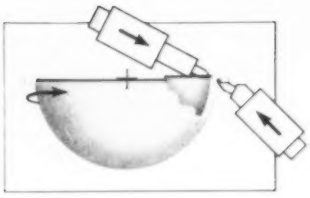
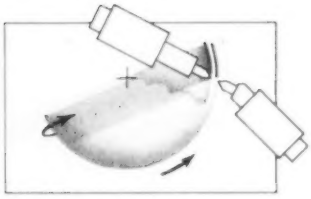
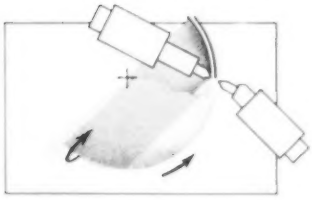
AIRCRAFT AND MISSILES MANUFACTURING

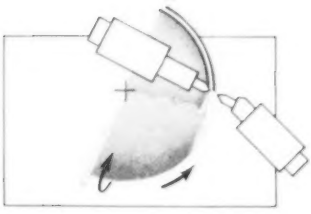
A CHILTON PUBLICATION

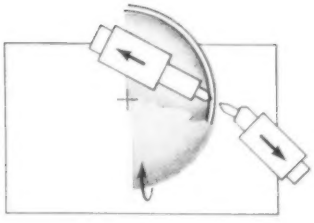
MARCH, 1958 · · DESIGN · PRODUCTION · PROCUREMENT

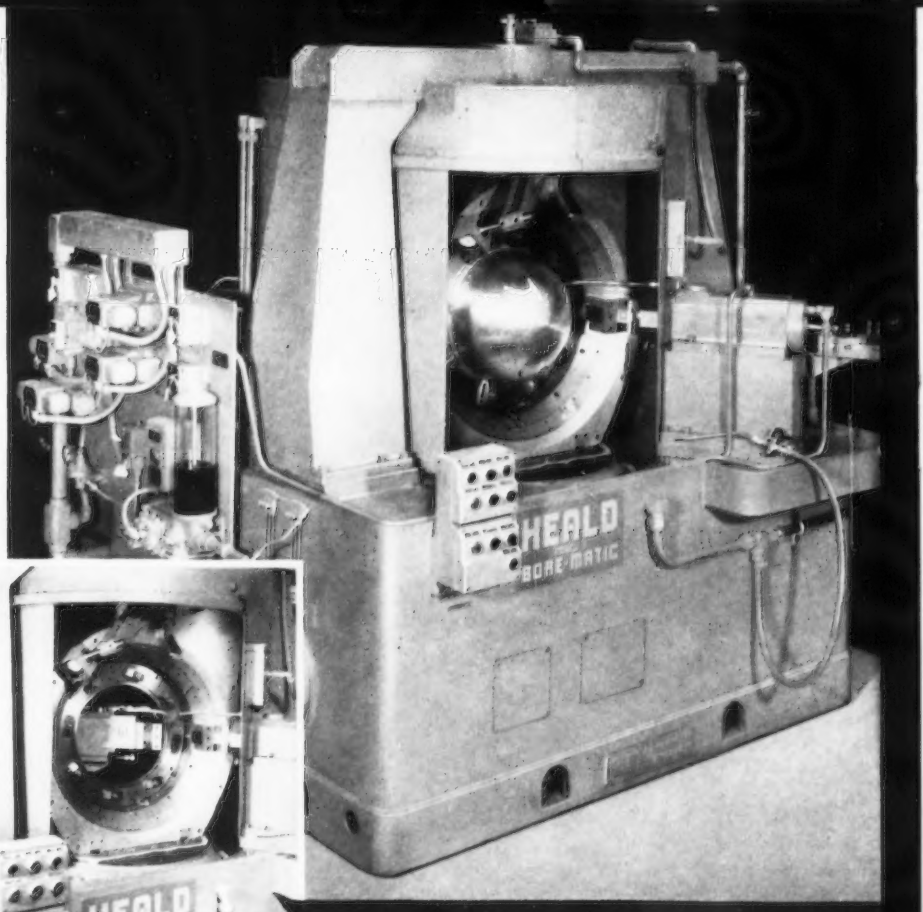












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SPHERICALLY BORIZED

on I.D. and O.D. Simultaneously

Putting a precision finish on aluminum hemispheres is the job done by the Heald Model "S" Bore-Matic shown above.

These large hemispheres require stock removal from both the I.D. and O.D., maintaining desired hemispherical shape and critical wall thickness.

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HEALD

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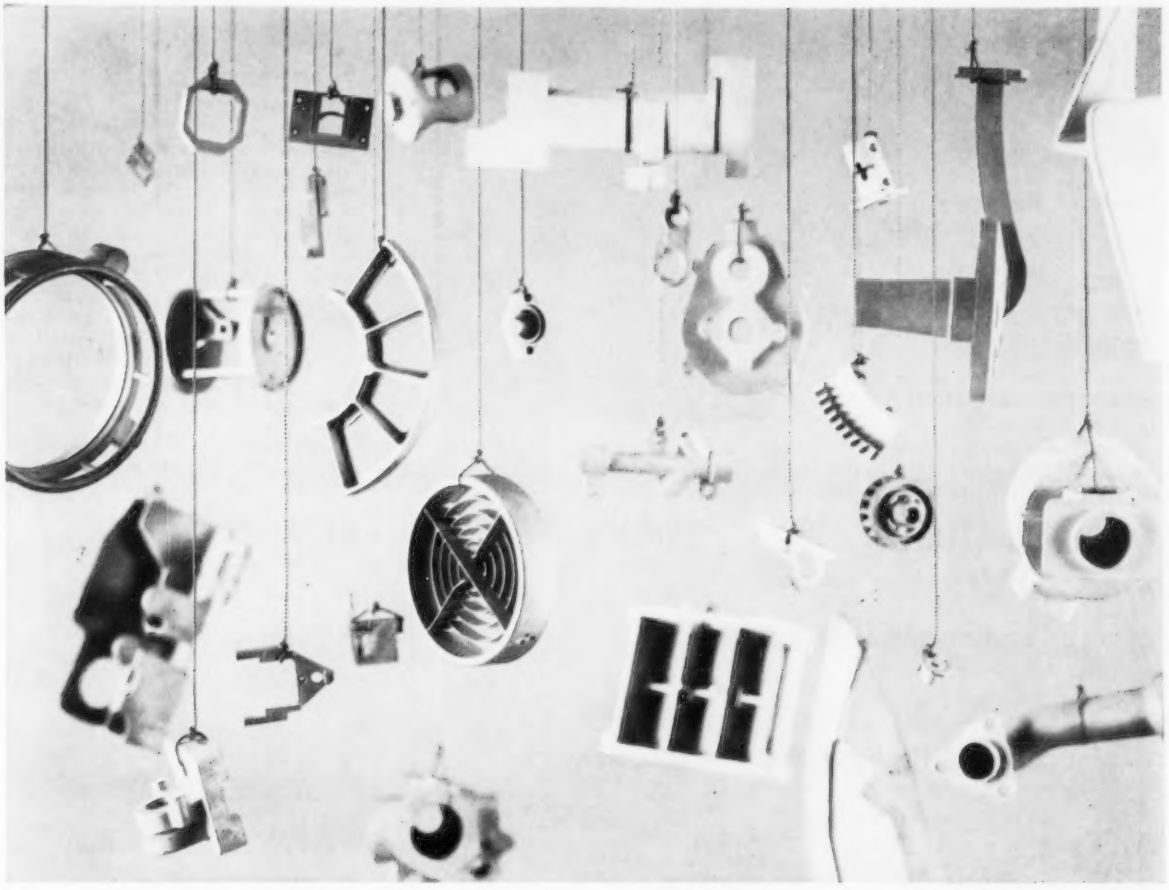

This assortment of castings represents about half the number of new parts that go into production at Arwood's five plants in a typical week.

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MARCH 1958

VOLUME 1, NUMBER 3

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PROCUREMENT

A CHILTON PUBLICATION

THE COVER STORY

Man's quest for better materials and structural concepts has led him even into the insect domain. He has borrowed the concept of the honeycomb from the industrious bee to produce stronger and lighter aircraft components. The efficiency of Nature probably holds numerous clues to help man solve many of tomorrow's problems. The supply of such clues can well be considered part of natural resources; but the effective utilization of these will be only as a function of man's unique power of imagination.

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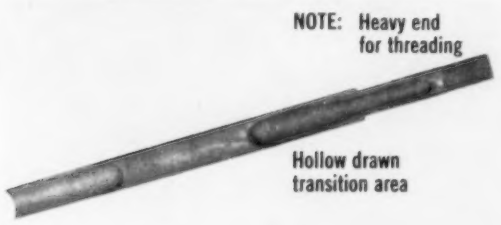

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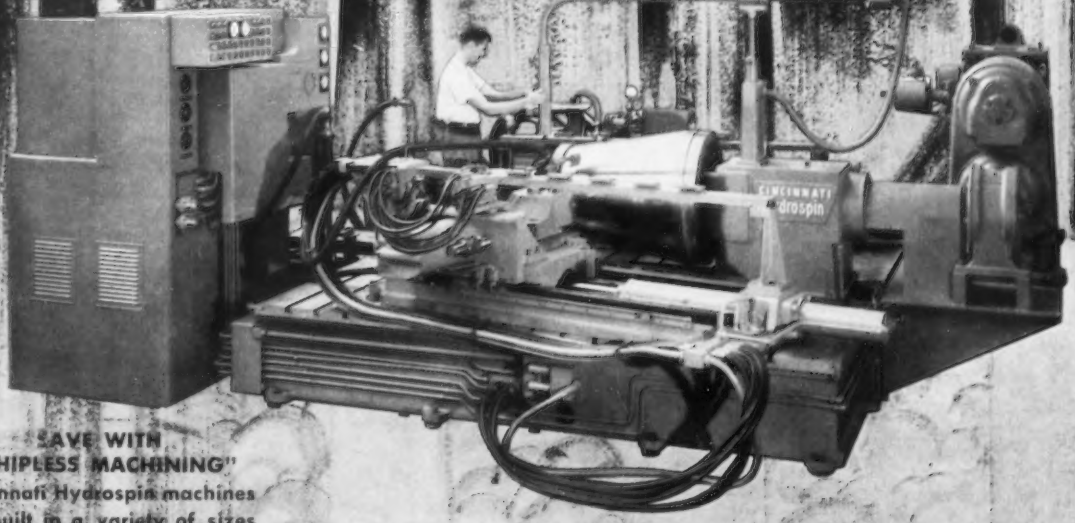

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Are we waiting for Sputnik III?

Explorer is up, and the country is down! We are complacent; we think we've matched the challenge of an unfriendly power. Now we can sit back with a smug look on our faces and say, "we did it, too." There are no more swords rattling in Washington. Scientists and engineers are again passing from the minds of the populace. There are now only half-hearted movements by the general public at more and better education.

The embers are going cold and so is our spirit. Do we, the famous selling nation, think that we can sit back and laugh in the face of competition, just because it has been met on one occasion?

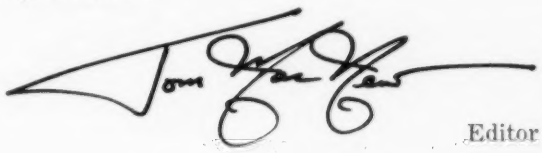
Don't we have any more of the good old fashioned Americans of '76; the rugged individualist of yesteryear who doesn't know the meaning of a "tied score"?

It is regrettable that the people of this country need a constant stimulant to keep them keyed-up. What do we need—repetitive setbacks by our antagonists? Everyone agrees that we need more money to put into the entire aircraft and missile program. Where is it? Has it been forgotten? Maybe we should start following the put-up or shut-up philosophy.

What are we trying to do—give unfriendly nations a handicap? It is about time we get off our hands and come to grips with reality. This is no sporting contest where we shake hands with the winner and walk off the field of combat. If we wish to retain our place in the World, we have but one suggestion, let's build for inventory. Build Thor, build Jupiter, Atlas, Polaris and others. Build more manned strategic and logistic aircraft. Let's put the aircraft people to work, instead of debating what service should have which project.

Would you walk from one oasis to another without a container of water? The water should be carried even if it were to be discarded at the next stop, but we would have a thirst preventive between stops.

So what if we have inventory that becomes obsolete? At least we have it at a time when it may be needed.



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AIRCRAFT AND MISSILES MANUFACTURING

THE 5:19 TO THE MOON

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- Cast insulation has formed entry ramp to provide easy wire insertion and snug fit over standard AN wires.
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- Step-Lok Crimp to guarantee continued proper position of insulation with respect to terminal.
- Connector designs are available in single to single, single to multiple and multiple to multiple wire accommodations.

The A-MP Ampli-NYL Terminal is installed with the proven Confined "C" Crimp for maximum electrical and mechanical performance. Confining the spread of the terminal during the crimping process achieves more intimate contact and a homogeneous union of conductor and terminal.

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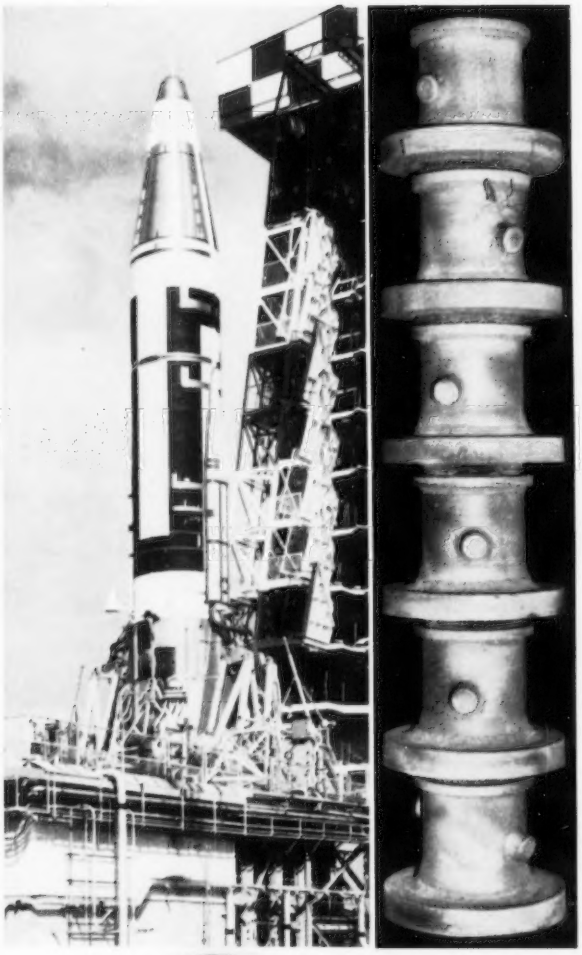
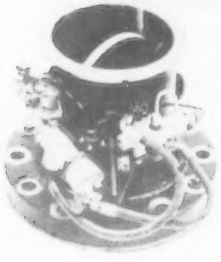
cast stainless valve bodies

centrifugally-cast, one-piece fuel valve bodies for Atlas eliminate multiple weldments, six bodies produced in one stick casting



Multiple stick casting technique produces six valve bodies in a single operation, reduces unit costs.



Completed butterfly valve assembly used to close a high pressure gas line on Atlas launching pad.

The cost of producing a butterfly fuel valve used in launching the Atlas ICBM has been reduced an estimated 30 percent as the result of a modified centrifugal casting technique which allows six one-piece valve bodies to be produced in a single casting operation.

The cast valve body replaces a multi-piece wrought welded design which had several shortcomings from engineering and cost standpoints. Machining and welding costs were high under the strict specification call outs. The fuel line, in which the valve is incorporated, carries corrosive gases at high pressures, inter-granular corrosion and gas leakage at weldment seams were feared.

Materials

Interstate Engineering Corp., designers of the valve, chose CF-8 type stainless (wrought 304) with 19 percent chromium, 9 percent nickel, and low (0.008 percent) carbon, as the material of construction because of its good resistance to corrosion in oxidizing media and good impact load absorption at low temperatures. The new valve was tested at temperature ranges from —65 to 500°F, at sudden loadings up to 15 gravities, and 2000 vibrations per sec.

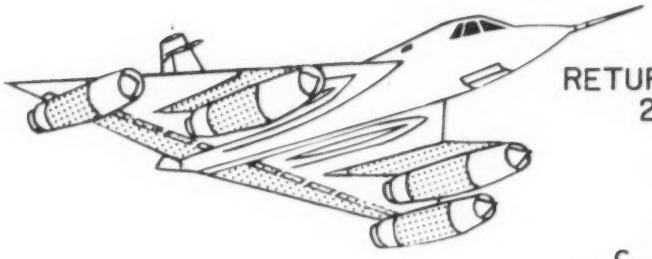
The valve is operated manually and is incorporated into a line carrying fuel to a high pressure tank in the ICBM. The butterfly valve must effectively seal gaseous pressures up to 150 psi since it is often desirable to clean and/or repair fuel lines without depressurizing the tank.

brazing Hustler's stainless sandwich

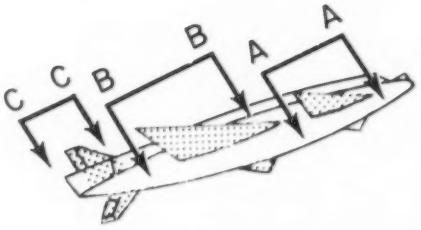
complete details on design, materials, and processing of furnace-brazed structures for the B-58

by A. A. Lanzara, design specialist, and R. E. Purnell, senior design engineer, Convair—Fort Worth

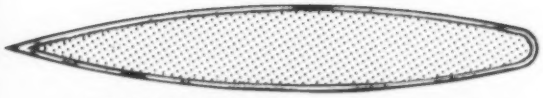
AREAS WHERE BRAZED STEEL SANDWICH IS USED IN B-58.



RETURN COMPONENT
230 PANELS

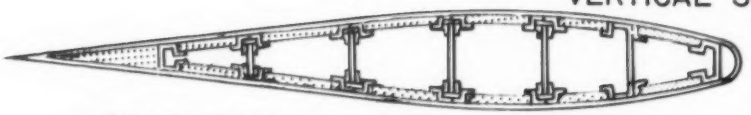


DETACHABLE BOMB POD
71 PANELS

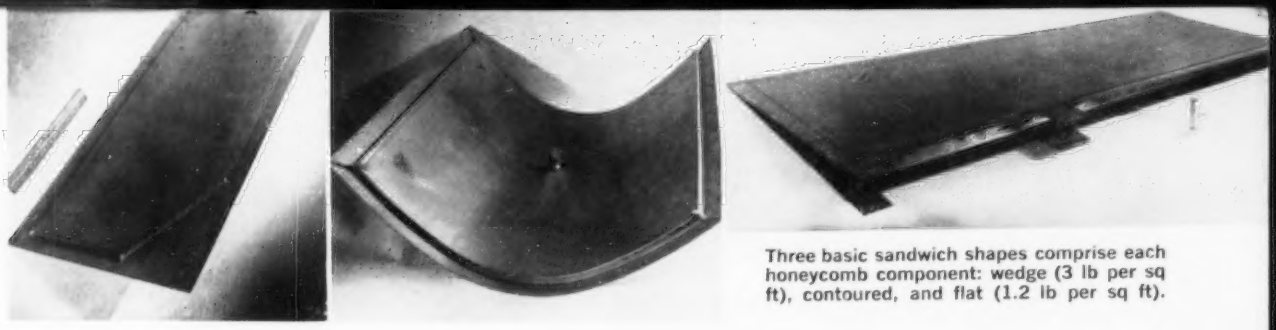


CROSSECTION OF CANARD
VIEW A-A

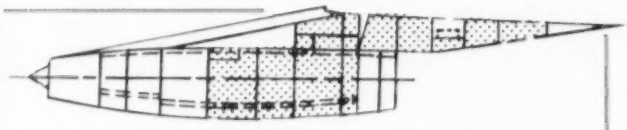
CROSSECTION OF UPPER & LOWER
VERTICAL STABILIZERS & RUDDER
VIEW C-C



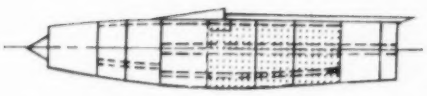
CROSSECTION OF WING VIEW B-B



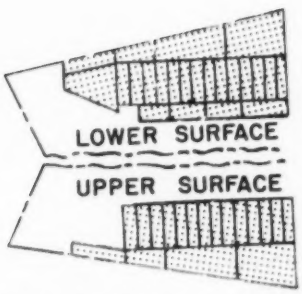
Three basic sandwich shapes comprise each honeycomb component: wedge (3 lb per sq ft), contoured, and flat (1.2 lb per sq ft).



INBOARD NACELLE L/R
86 PANELS



OUTBOARD NACELLE L/R
36 PANELS



WING TRAILING EDGE & ELEVON
108 PANELS

The transition to high speed and resultant elevated temperatures in aircraft operation has been so rapid that research and development in materials and structural design has not kept pace with advances in engines and aerodynamics.

In designing and building the delta wing B-58 Hustler, Convair was faced with this problem. At the predicted operating temperatures it was not possible to meet the rather flexible weight limitations using conventional structural designs.

The solution to this problem was the extensive use of sandwich construction, both bonded and brazed. The sandwich design fulfilled the requirement for a primary structure that could operate at comparatively high temperatures without penalizing performance through excessive weight.

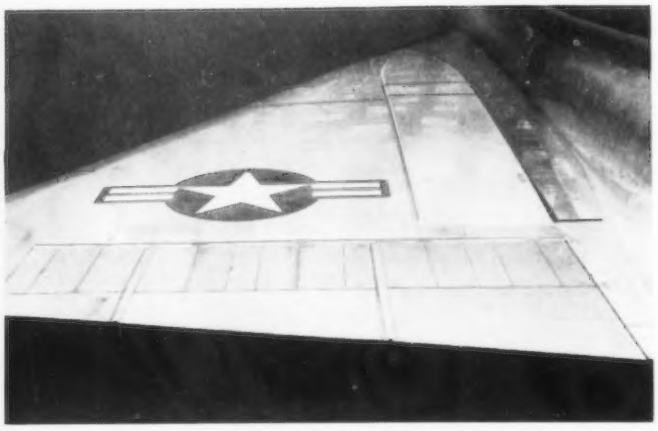
At the time the basic design was finalized, 300°F was established as the upper operational limit for adhesive bonded structures. This dictated the use of stainless steel brazed sandwich throughout the elevon and nacelle struts, and on portions of the wing and engine nacelles, since these areas might reach or exceed 300°F at maximum performance.

Total area of brazed construction is approximately 870 sq ft; a small percentage of total airframe area, but an overwhelming task at the outset.

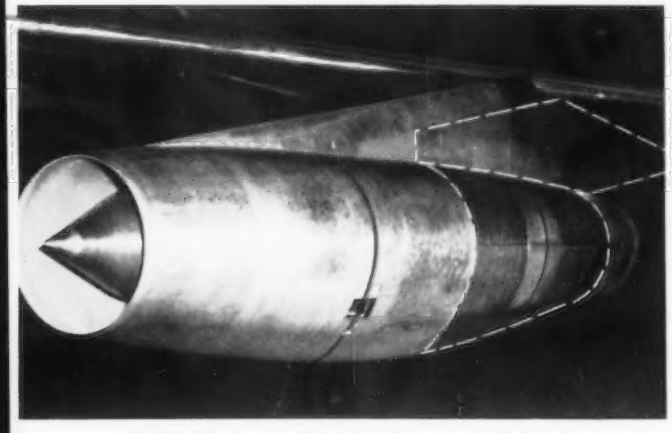
Materials

Regardless of size or shape, the basic makeup of the B-58 brazed sandwich panel is the same, and with very few exceptions so is the processing. A typical panel consists of preformed edge closure members, flat or angle doublers, welded steel honeycomb, inner and outer faces all integrally attached by a silver-brazing alloy. The specific materials in use on the B-58 are 17-7PH corrosion resistant steel for facings, core and detail parts, and a sterling silver plus lithium brazing alloy. The core is resistance welded 3/16 in. cells, square in shape, with a foil thickness of 0.0015 in.

brazing Hustler's stainless sandwich continued

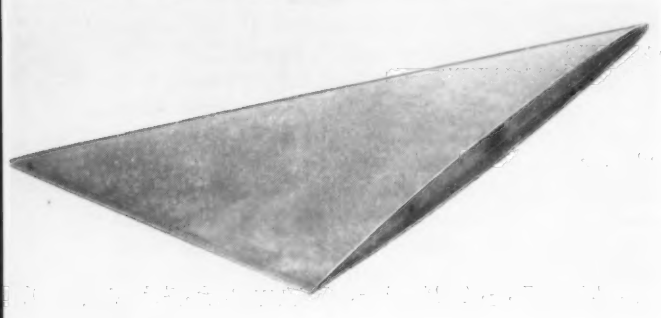


Three wedge shaped sandwiches with full depth core make up the elevon. Core tapers from 4 1/2 to 1/16 in. Upper surface of left wing is shown here.



Steel sandwich is used throughout the nacelle struts (except leading edge). Aft portion of nacelle (dark area) is made up of highly contoured honeycomb panels.

Airfoil sections of the detachable pod are made of full depth core, and surface mated panels.



Three Basic Sandwich Shapes

Three general shapes of brazed steel sandwich panels are used on the Hustler: flat, wedge shaped and contoured. The flat panels are located on both the upper and lower surface of the forward elevon box. Average size for these panels is 5/16 x 16 x 40 in. Facing material is 0.005 to 0.010 in. thick. The panel weight is approximately 1.2 lb per sq ft.

The three large panels on the elevon trailing edge are typical wedge shaped sections. They are double surface panels; that is, both surfaces are exposed to the air stream. The core is full depth and is machined to conform to panel contour. The largest of these is approximately 40 x

In assembling contoured panels, core is tack brazed to skin and edge members on a male mold. Worker wears clean rubber gloves to prevent contamination of the cleaned parts by skin oils.

Edge members are also tack brazed in assembling flat panels. Nugget of brazing alloy will remelt in the furnace brazing cycle. Tack brazing operation is performed with a portable spot weld power supply.

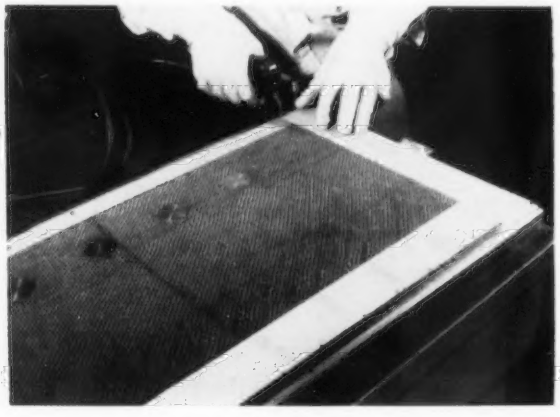


TABLE I

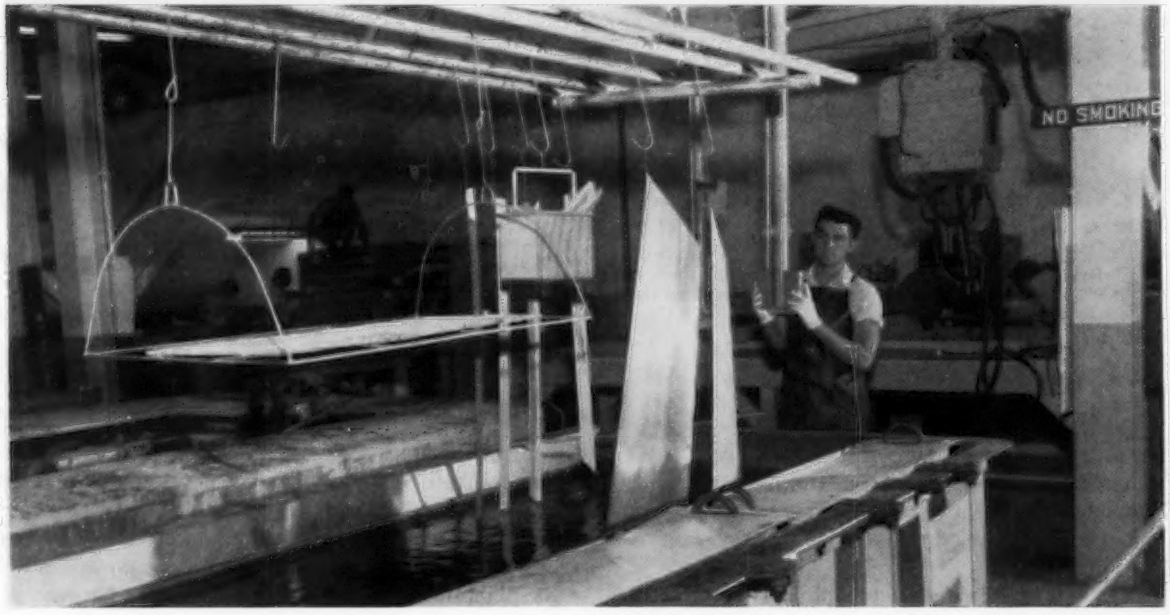
CLEANING PROCESS FOR ALL 17-7PH DETAILS

Step	Process	Solution Composition	Solution Temp.	Time
1	Vapor degrease	Stabilized trichlorethylene	225° F	10 min.
2	Alkaline clean	Oakite No. 90: 8–10 oz. per gallon	180–190° F	20–30 min.
3	Rinse (constant overflow)	Tap water	120–140° F	10 min.
4	Acid clean	Sulfuric acid—20 per cent by volume Nitric acid—10 per cent by volume Hydrofluoric acid—2 per cent by volume Sodium dichromate—1 per cent by volume	Room temp.	10–20 min.
5	Rinse (constant overflow)	Tap water	120–140° F	3 cycles 2 min. each
6	Spray rinse	Distilled or de-ionized water	Room temp.	30 sec. min.
7	Dry	Room temp. or hot air	140° F max. until dry	

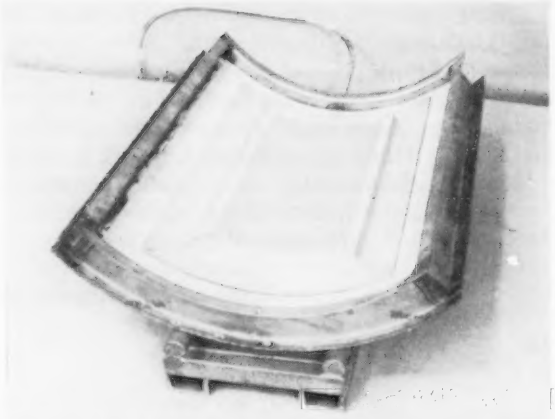
TABLE II

CLEANING PROCESS FOR Ag-Cu-Li BRAZING ALLOY

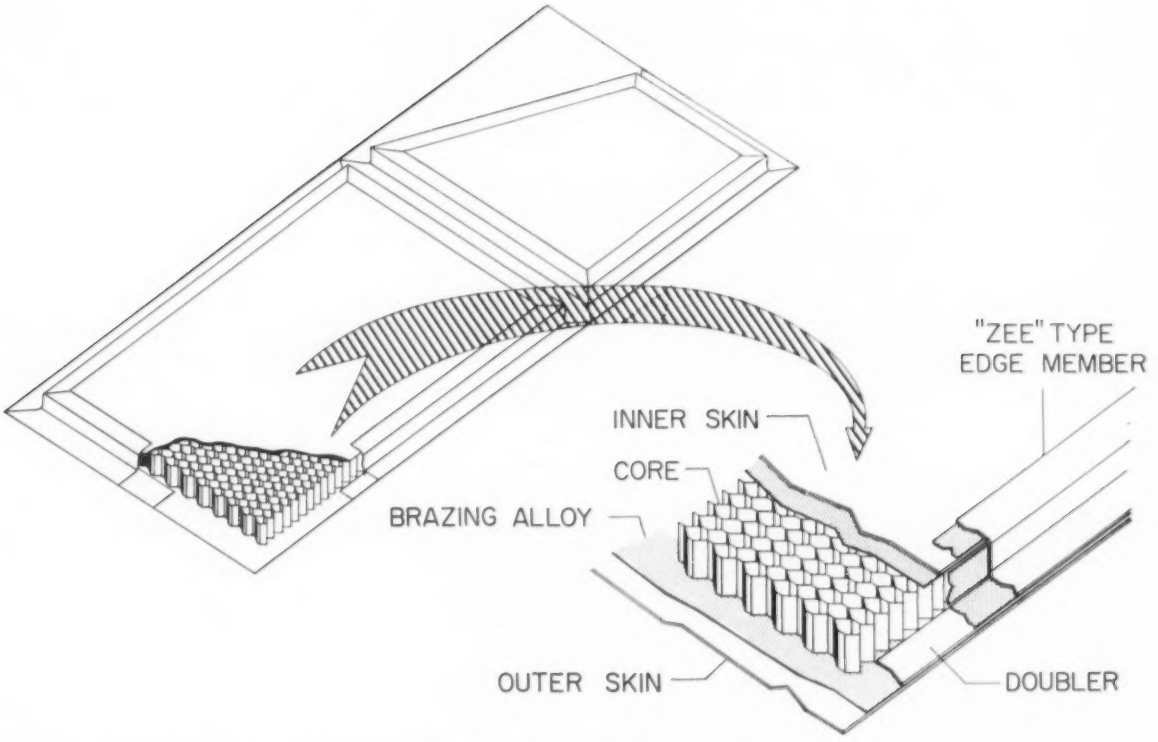
Step	Process	Solution Composition	Solution Temp.	Time
1	Vapor degrease	Stabilized trichloroethylene	225° F	10 min.
2	Alkaline clean	Oakite No. 90: 8–10 oz. per gallon	180–190° F	2–3 min.
3	Rinse (constant overflow)	Tap water	120–140° F	10 min.
4	Spray rinse	Distilled or de-ionized water	Room temp.	30 sec. min.



All sandwich components are chemically cleaned. Core is placed on a tray, short members in a basket, long edge members and skins are suspended from wires.



Completely tack brazed panel is placed on a graphite block then set in the brazing box. Steel bar formers will be placed around the panel edges, and a vacuum diaphragm welded over. Vacuum line can be seen in rear.



Regardless of size or shape, all B-58 sandwiches are comprised of these basic parts. Preformed edge closures, doublers, core, and faces (all 17-7 PH), joined by silver-lithium brazing alloy.

72 in. The depth tapers from 4½ in. to 1/16 in. at the trailing edge closure fitting. Facing thickness is 0.008 or 0.010 in. An average density for this type of construction is about three lb per sq ft.

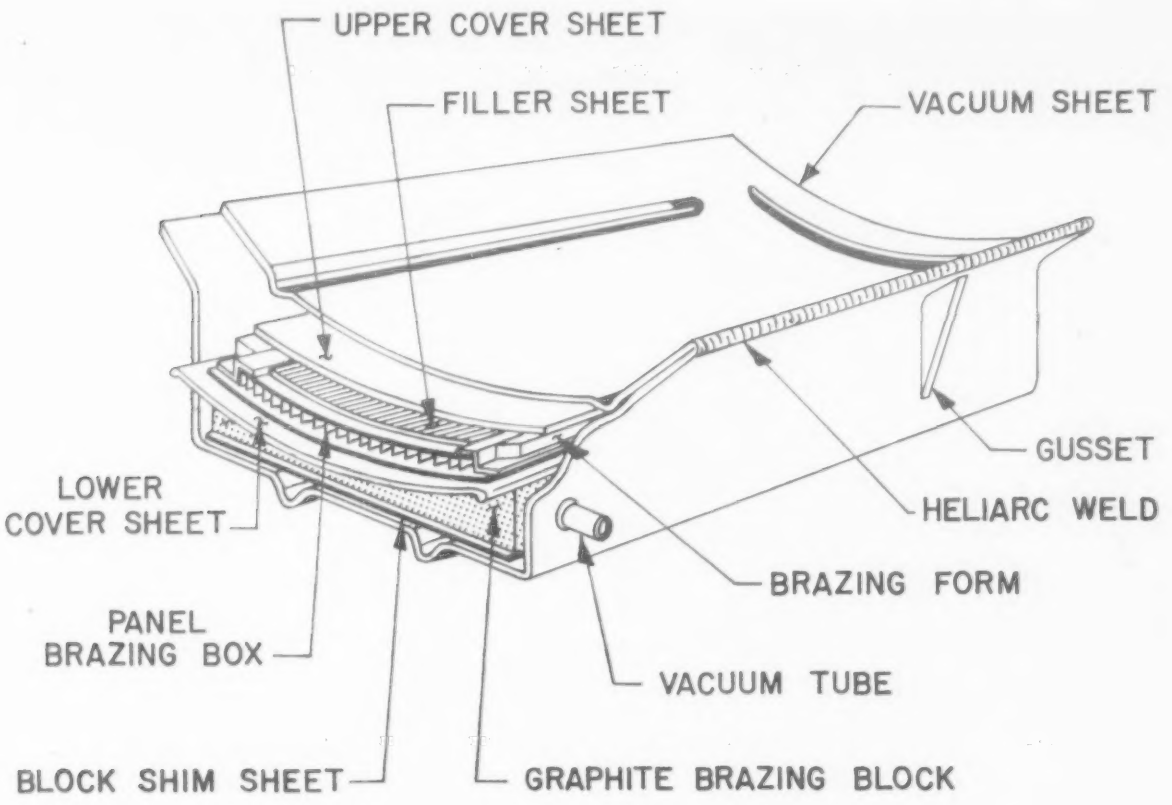
As an indication of the efficiency of the brazed sandwich construction, a steel sheet and stiffener design of equal load capacity would cost about 632 lb per airplane.

The third general category is the contoured surface panel. The hotter portions of the engine nacelles are made up of these double contoured panels. A typical panel is 32 x 38 in. and the radius is approximately 22 in. Skin thicknesses are normally 0.005 or 0.008 in. on the inner surface, combined with 0.008, 0.010 or 0.012 in. on the outer.

Very slightly contoured panels are used on the inboard engine nacelle struts. Some of these panels, being heavily loaded, contain thick edge members and facings as compared to the brazed steel sandwich in other locations on the airplane. Face materials and edge members run as heavy as 0.062 in. Even so, maximum density for panels in this location is only 4.1 lb per sq ft.

Tolerance Build-Up Troublesome

One of the main design considerations affecting producibility is that of tolerance buildup between core and preformed edge closure members and resulting excessive mismatch on assembly. This results in unbrazed areas at the panel perimeter, normally the load introduction area. Permissible mismatch is influenced by several factors: brazing temperature, brazing pressure and the flow and wetting characteristics of the



Cut-away section of complete brazing setup.

brazing alloy. In the B-58 sandwiches, a height tolerance of only ±0.003 in. on both the core and edge members is allowable. These close tolerances required the development of a specialized family of inspection tools. Training programs were initiated to educate shop and inspection personnel as to the necessity for such tolerances. Lowered rejection rates and lowered production costs have been an apparent result.

Any mismatch between the core and edge members becomes apparent in a trial assembly and appropriate rework is initiated.

Components Cleaned Meticulously

The facing material is cut to finished size and all the component parts proceed to the cleaning operation. This consists of vapor degrease, acid or alkaline bath and water rinse. The cleaning and rinse tanks are used exclusively for cleaning brazed assembly details. This prevents contamination of the tanks by other materials. Following the cleaning operation and continuing through assembly, parts are handled with clean rubber or cloth gloves. This precaution is necessary since any perspiration, oil or dirt from the worker's hand will effectively prevent the brazing alloy from wetting the contaminated area and result in unbrazed areas or voids.

The parts are then sent to the assembly area. This is a large enclosure that is kept free of dust. A slight positive pressure is maintained in the room to prevent contaminants such as acid vapors, smoke, and dust from entering. The interior of the room is well lighted and painted white. These cleanliness requirements, based on solid judgment and experience, are a necessary part of the overall process.

Final Assembly

As the final assembly proceeds each component part is tack welded or tack brazed into position. This prevents any shifting or relative movement of the parts when the completely assembly is removed from the assembly fixture.

Following assembly, the panel is placed on a graphite block mated precisely with the panel. Panel and block are placed in a stainless steel box-like container. The cover of this brazing box is a relatively thin steel sheet, usually 0.010 or 0.012 in. thick. It also conforms to the surface

brazing Hustler's stainless sandwich

continued

Vacuum diaphragm is a 0.010 to 0.012 in. steel sheet. Diaphragm and steel sheet cover over graphite block are coated with stop-off material (white) to prevent brazing alloy run off from joining these sections to the sandwich.

Brazing box with steel diaphragm welded in place is purged with dry argon and put in the brazing furnace. Vacuum pump than applies 14 to 20 in. Hg atmospheric pressure.

contour of the panel. In the case of severely contoured panels, the steel sheet is actually stretch formed on the same die as the sandwich facing. After the cover is welded on, the container is pressure checked to insure that it is gas tight and then purged with pure dry argon.

Brazing Cycle

The brazing box is placed in a retort purged with dry argon and then placed in the furnace. A pressure is induced on the brazing box by connecting it to a vacuum pump; this causes the thin steel diaphragm to press down and exert a uniform pressure over the surface of the panel beneath it. The maximum permissible pressure is a function of the material, the brazing temperature, the height of the core, panel size and shape. Currently a pressure of 14 to 20 in. of mercury is used at Convair depending on the combination of these factors.

The panel temperature is raised rapidly to the brazing temperature of 1650°F and held there for a short time. The temperature is then cut back to 1400°F and held for 90 min to accomplish the first portion of the heat treatment. The part is then cooled to room temperature, refrigerated to −20°F to insure complete transformation and finally age hardened at 1050°F.

Inspection

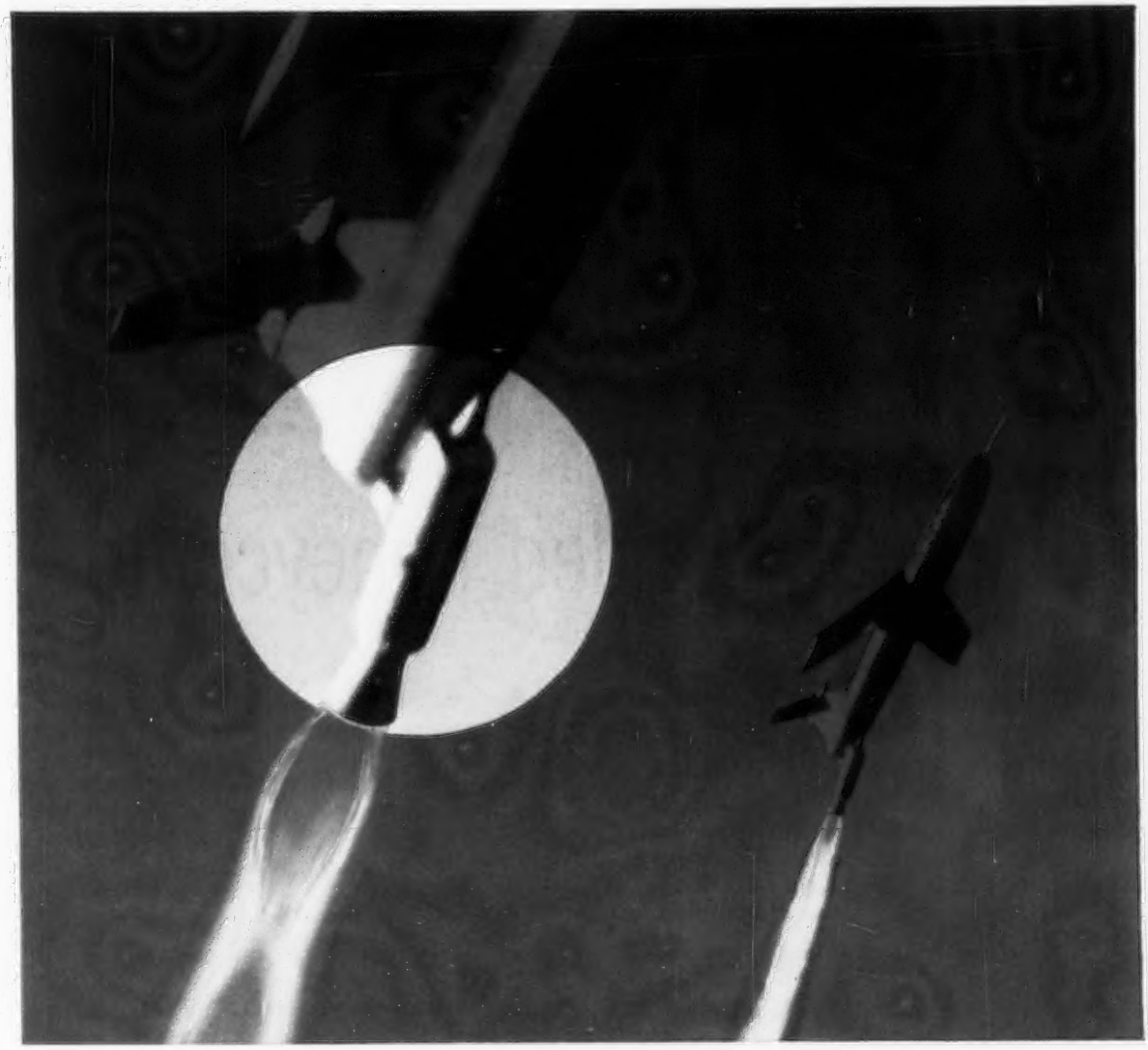
Extremely close inspection and control of processing is maintained throughout, and is definitely necessary. Defective cleaning or assembly, poor atmosphere, improper heating, defective brazing tools can cause scrappage.

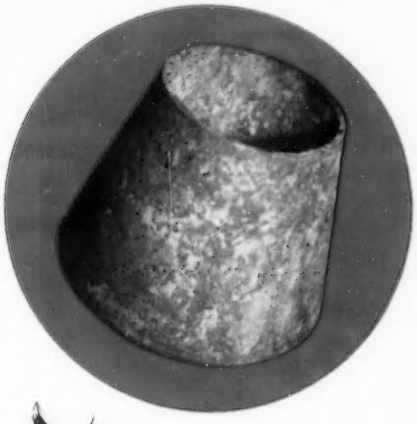
In addition to normal dimensional and contour checks, post-braze inspection consists of tests to determine both heat treat response and the quality and completeness of the braze. The heat-treatment is checked by tensile tests of excess facing material provided in the panel design for this purpose. The extent or completeness of the braze is checked by radiographic inspection.

Braze strength in the core areas is checked by means of flash heating. This consists of heating small areas of the facing very rapidly by means of quartz heaters to induce thermal stresses. Temperature (usually 600° to 800°F) and resulting stress are controlled automatically by a preset exposure time varying from one to four seconds. A weak braze will immediately fail.

The end product is a primary stainless steel structure usable up to 900°F. It retains its aerodynamic smoothness without thermal wrinkling or canning. It has excellent fatigue resistance. Tests have been run on a full production elevon mounted directly behind both J-57 and J-79 engines for many hours of engine operation. The brazed sandwich has consistently proved to have better fatigue life than its fasteners or the structure to which it is attached.

The fact cannot be overemphasized that the design and performance of future aircraft will be limited by material deficiencies more than any other factor. In this field is the key to the aircraft and weapons of tomorrow. Steel sandwich is only the first step, it is however a major breakthrough in conquering the "thermal thicket."





ONE-PIECE WELDED CONE FOR THE HOT SPOT

This is the vital nozzle cone of the Martin Mace guided missile. American Welding was able to form it in one piece from ¾-inch plate (FS-1020) and arc weld the joint to produce a tapered cone with a major diameter of 25 inches and a minor diameter of 15 inches. After heat treating and X-ray testing, it proved to be better and more economical than nozzle cones produced by the previous method of forming in two halves.

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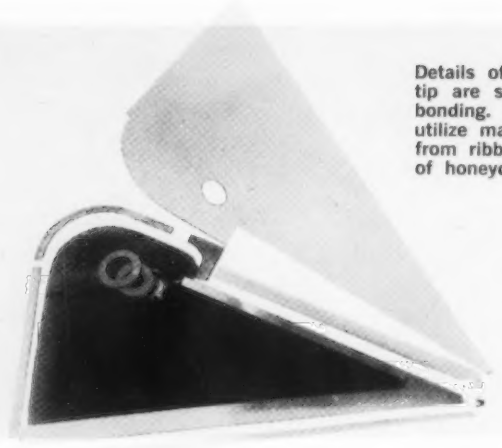
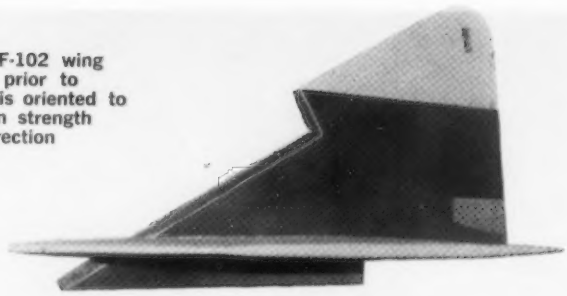


Details of the F-102 wing tip are shown prior to bonding. Core is oriented to utilize maximum strength from ribbon direction of honeycomb



Section of F-102 vertical fin tip is constructed of bonded honeycomb sandwich.

adhesively-bonded honeycomb

"art of gluing" refined with increased use of sandwich in aircraft and missiles

by **Harold Rosenbaum**, design specialist, Convair—San Diego

Modern airframe fabrication was once defined as "drilling of a lot of little holes in pieces of metal and then plugging them up again with other little pieces of metal." This of course is not entirely accurate.

The use of rivets and other types of mechanical fasteners has been standard practice for airframe assembly since the advent of the first all-metal airplane. The disadvantages, and limitations of these fasteners have long been recognized and ways of designing around them have been devised. But problem areas still exist and new fabrication methods must be found or old ones modified.

New Science Is Old Process

One of the methods now employed is as "old as the hills." In fact, it was used to assemble wood and other non-metallics in ancient times. The gluing process as practiced up to 25 years ago has now given way to the science of adhesive bonding. This can be attributed in part to the development of new materials capable of adhering metal to other metals and non-metals, with good physical properties in the resulting assembly.

Perhaps the greatest use of these new adhesives is in sandwich construction. Sandwich construction is a relatively new airframe building concept which has been adopted, in varying degrees, by most airplane manufacturers. Basically, the sandwich is composed of thin, strong, and dense facings separated from each other by a relatively thick, lightweight, and weak core. The facings, which are the load carrying members, are generally made from aluminum, plastic laminates, stainless steel, or plywood. The core, which supports the facings, is generally made from aluminum, plastic fiberglass laminates, plastic paper laminates, plastic foam, stainless steel, or balsa wood.

Sandwich Is a True Structure

There are literally hundreds of possible combinations from which a structural sandwich can be made. Therefore, it is necessary to consider the sandwich as a true structure rather than a material of construction. When properly

Some of the areas where adhesively bonded sandwich is used in the F-102: (A) Cockpit side panels (riveted and bonded), (B) Fuselage access doors. (C) Wing fence inboard (D) Wing fence outboard (E) Wingtip (F) Rudder (G) Elevon trailing edge (H) Vertical fin tip.

engineered and fabricated the sandwich structure is characterized by excellent strength-weight ratio, good rigidity, and simplicity of design.

In appearance the core is much like the honeycombs made in nature by honey bees, hence its name. The cores most widely used at present for adhesively bonded aircraft structural sandwiches are made from 3003H-19 and 5052H-39 aluminum foil joined to form a hexagonal pattern. The aluminum honeycomb core is available in hexagon sizes from $\frac{1}{8}$ in. to $\frac{3}{8}$ in. across the flats. The foil thickness varies from 0.0007 to 0.006 in. so that it is possible to obtain cores varying in density from 1.6 to 10.5 lb per cu ft.

Strength

The strength of the core varies directly with the density. That is, the heavier the core the greater the load it will sustain. Therefore, a knowledge of the mechanical properties of the core is needed to assure maximum efficiency in sandwich structures.

Another complicating factor, is that honeycomb cores have directional properties somewhat like those of wood. Just as wood is stronger in bending with the grain than across it, so is honeycomb stronger in the ribbon direction than it is across the flats of the hexagons (Fig. 1). The strength in the weak direction is roughly 60 to 80 per cent of the strength in the strong ribbon direction. It is necessary to orient the core so advantage is taken of its maximum strength direction in the final component.

Sandwich structures can be made either flat or contoured. The shapes can vary from a simple single contour to complex double contours. Various types of edgings and inserts can be incorporated in the structure for attachment to other structures or for protective purposes. Edgings are often made of laminated plastics, metal shapes, or cast plastic. Inserts may be cast plastic, wood blocks, or metal spacers. Their function is to prevent local crushing of the core under bolt or screw tension and to spread loads over a larger area to reduce load concentrations.

A sandwich structure is only as good as the process used to produce it. Once a satisfactory process has been developed it should and must be kept under control by strict policing and adequate testing. Controls for the cleaning solutions must be sensitive enough to detect even slight changes in the concentration of the ingredients so that uniform batch-to-batch cleaning is obtained. Likewise, controls for adhesive application and bonding cycles must be established and carefully followed.

Sandwich in F-102A

The success with sandwich components on the Convair-Liners stimulated its use on the Convair F-102A all-weather interceptor. The sandwich structures on the F-102A are mainly on the exterior of the airplane and are classified as primary structures. The wing tips and fin tip are complex sandwich structures having airfoil contours. They are made of aluminum skins and aluminum core bonded with a high temperature resistant adhesive. The trailing edge of the elevon is a wedge shaped all-aluminum sandwich structure bonded with the same adhesive. The rudder also is a wedge shaped aluminum sandwich bonded with the same high-temperature resistant adhesive.

Mounted chordwise on the delta wing of the F-102A are two sets of "fences" which are

made of flat sandwich. These fences were required to be very rigid without being unduly heavy. Sandwich construction was the ideal solution for these components.

The fuselage of the F-102A has several access doors which are designed to carry loads as well as cover holes. Three of these doors are made of sandwich. They are complex contoured components that are made in matched metal molds. Two engine access doors and a ram air turbine door comprise this group.

adhesively-bonded honeycomb

continued

SANDWICH FABRICATION

In general, the process for sandwich production, as practiced in this country, consists of the following steps:

1. Fabricated metal details such as edge members and inserts, are inspected for tolerance and fit.

2. The core is cut to size and, if necessary, contoured.

3. The sandwich facings are cut to size and, when necessary, formed to required contours.

4. All gross soil, such as identification marks, grease, and oil are removed from the metal by hand wiping with a solvent such as methylethyl ketone.

5. The parts are immediately vapor degreased using stabilized trichloroethylene.

6. The parts are then immersed for 10 min in a solution consisting of 10 parts sulfuric acid, 1 part sodium dichromate, and 30 parts of water, the temperature of the solution being maintained between 140 and 160°F.

7. Immediately after removal from the acid tank the parts are thoroughly rinsed in running water. At this point the metal surfaces are examined for breaks in the film of water adhering to the metal surfaces. A break indicates an improperly cleaned surface, and the part must be reimmersed in the acid solution for recleaning.

8. After most of the water has drained from the surface of the metal, the parts are dried at a temperature not exceeding 150°F in an air circulating oven. From this point on, the handling of all cleaned metal details must be done by workers using clean, white, cotton gloves.

9. The facings and details to be bonded are spray or brush coated with a diluted solution of the adhesive. The thickness of the coating or primer after it has dried is usually 0.0005 to 0.0015 in.

10. The core, after cleaning with solvent, or by the sulfuric acid-sodium dichromate method, is roller coated with adhesive primer. The thickness of the primer on the core edge is usually about 0.030 in.

11. After air drying from 10 min to several hours the primed details are baked in an air-circulating oven for about 30 min at 235° to 250°F. At this point the details may be stored by wrapping them in clean paper, or some comparable material. Details may be stored up to 90 days prior to use, in some cases, provided that the wrappings remain intact and the details are not contaminated by exposure to the atmosphere.

When a film adhesive is used, a layer of the adhesive is placed between the core and facings during the assembly of the details. The film is also placed between the mating surfaces of other details of the structure.

12. If curing of the assembly is to be accomplished in a press, the assembly may be covered by a resilient blanket of heat resistant rubber. The covered assembly is placed on the bed of the press and pressure is applied. The temperature and pressure are carefully controlled so that the cured adhesive yields optimum strength bonds.

If the assembly is to be cured in an autoclave or pressure vessel, a flexible bag of rubber or plastic is placed around the assembly to check for leaks in the flexible cover. If no leaks are apparent the assembly is placed in the autoclave and heat and pressure are applied.

13. After trimming to size and cleaning, the completed assembly is ready for use.

The process is quite often modified to suit the particular conditions required for a given adhesive system. For example, some adhesive systems do not require priming of either the facings or the core. Others require priming of the facings but not the core. Some adhesives are completely liquid while others are thin films either supported or unsupported. Epoxides, epoxy-phenolics, rubber-phenolics, and vinyl-phenolics are a few of the types most widely used for structural sandwiches. Each type or system has its advantages and disadvantages in strength, processing, temperature resistance, and cost.

Advantages

The F-102A components were designed in sandwich because this type of construction offered several important advantages over the conventional type of aircraft construction. The fact that a weight savings could be effected through the use of sandwich was of prime importance. For example, a total of 15 lb was saved on the wing tips, 7 lb were saved on the rudder, and 8 lb were saved on the wing fences.

Another important advantage of sandwich construction was that, in several instances, the cost of producing these items was considerably less than the cost of the same items made in the conventional manner. The third advantage of the sandwich construction was that the entire surface of the structure was stabilized and therefore did not flutter or vibrate under aerodynamic loading. In addition to these advantages, the surfaces of the sandwich components are aerodynamically smooth and therefore offer less resistance in flight.

Face to Core Bond Difficult

The ideal sandwich is difficult to achieve because of the problem of attaching the facings to the core. One successful method has been by furnace brazing. This method requires that both the component and its tool be heated to above the flow temperature of the brazing alloy in an inert atmosphere in a carefully controlled furnace. The success of the process is dependent upon strict adherence to carefully tested procedures. (See "Brazing Steel Sandwich," this issue.)

There are several processes now under development which may make it possible to produce brazed stainless steel sandwich structures at costs much lower than those of the present furnace brazing methods. One new process utilizes the principle of resistance heating of the component and its fixture without the use of a furnace.

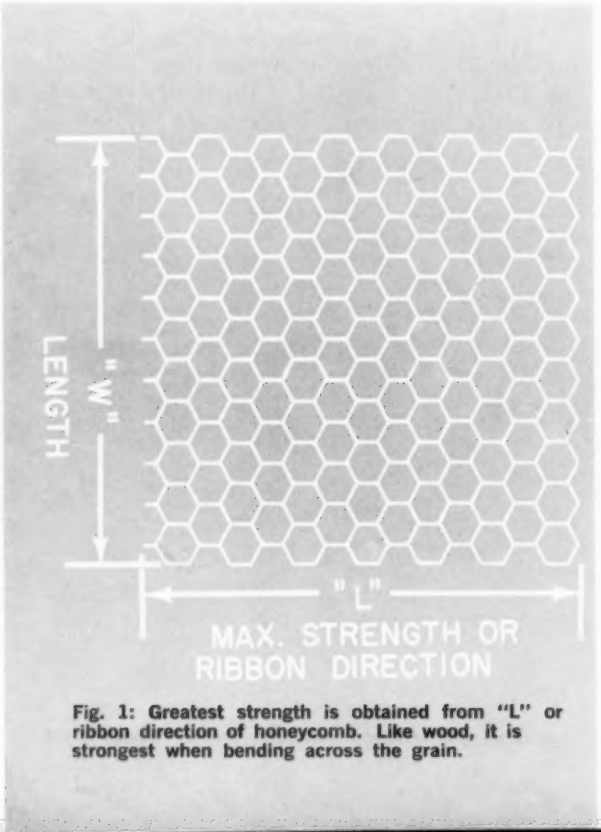


Fig. 1: Greatest strength is obtained from "L" or ribbon direction of honeycomb. Like wood, it is strongest when bending across the grain.

Testing Problems

One of the most serious problems of sandwich construction is the inspection or determination of the quality of the adhesive bond. It is possible by various techniques to detect unbonded areas in both the sandwich and metal-to-metal surfaces. There are several variations of the "coin tapping" method to detect voids, and there are several ultra-sonic and electronic methods. The Stub Meter, developed under contract to the United States Air Force by Stanford Research Institute, operates on the principle of mechanical impedance of ultra-sonic vibrations. This device is capable of detecting areas of poor or marginal bonds as well as unbonded areas.

Even though non-destructive test techniques are available, confirming destructive tests are still considered mandatory. Units selected from a carefully planned sampling schedule are either cut into samples and tested or set into fixtures and loaded to destruction under conditions simulating actual use in the airplane. The destructive tests serve as a check on every step in the process.

It is also customary to fabricate at least one quality control sample with each part. The sample is made from the same facing and core as the production part and the same adhesive is used. The details of the specimen are processed along with the details of the part and are cured at the same time and in the same tool. The sample is generally tested to determine skin compression strength, core shear strength, and facing to core peel strength.

The advancing technology of high-speed, high-performance aircraft is threatening to surpass the working limits of presently available materials. More and more emphasis is being placed on high strength stainless steels as the solution to the thermal problems encountered in high-speed aircraft. Many designers believe that the most efficient way that these high-density materials can be utilized is in the form of a sandwich having thin faces and a relatively low density core.

truss-core sandwich structures

skins welded to core halves prior to sandwich assembly in novel design

by Joseph W. Semonian, Zahorski Engineering, Inc.

The expression "sandwich plate" is associated with a structural configuration that is becoming commonplace in aircraft and missile manufacturing. Its applications are extensive and include aircraft and missile fuselage sections, bulkheads, speedbrakes, fuel tanks, heat exchangers, shipping containers, nuclear reactors and many others. It has proven to be extremely reliable for the high strength, elevated temperature environments in which we are operating today.

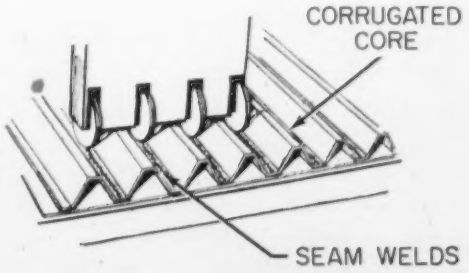
Basic Problems

A growing interest in sandwich construction justifies a discussion of some of the problems encountered by structures engineers and production specialists. The design problem lies in selecting a material for face and core which satisfies the stiffness and strength requirement of the customer's specification. The manufacturing problem lies in producing a core, combining it with the facing material, and making certain the final product meets all engineering specifications and reliability demands.

The sandwich structure fundamentally consists of two facing plates separated by a lightweight core. A configuration of this nature is capable of transmitting loads applied both normal to the faces and in the plane of the faces.

The effectiveness of any sandwich plate depends not only on the degree of excellence of fabrication, but on how well the design of the sandwich suits the particular function for which it is intended. A large number of variables are encountered in designing a sandwich plate structure.

The design of an efficient sandwich structure is not an insurmountable problem, however. The principles of optimum design set down by A. Zahorski in *Journal of Aeronautical Sciences*, July 1944, may be applied to the design of sandwich plates for elevated temperature use just as



readily as they have been applied to the design of sandwich plates and sheet-stringer panels for room temperature use.

For the idealized truss-core sandwich plate in pure compression the optimum shape is found to be very nearly one formed by equilateral triangles having the same thickness in the core and faces. The procedure in elevated temperature design is exactly the same as that stated except that the stress-strain properties used must be those obtained at the required temperature after a specified exposure to this temperature. Curves for the optimum design of steel honeycomb sandwich plate have been given (*NACA/TN 3751, 1956*) for both room temperature and 600°F, it was shown that properly designed steel sandwich plate can be more efficient for some applications at 600°F than conventional construction is at room temperature. This remarkable achievement is the result of the inherent qualities of sandwich plates coupled with the principles of optimum design.

In a comparative study of different kinds of sandwich plate (*NACA/TN 4009, June 1951*) it was shown that the most efficient basic design depends upon the magnitude of the load to be carried and the unsupported span length over which the load must be carried. For light loadings or large values of span length, the honeycomb-core sandwich plate was found to be highly efficient. For heavier loadings or shorter panel lengths a prismatic truss-core sandwich, sometimes called "cardboard box sandwich," was found to be more efficient.

In Figure 1 it can be seen that less weight is required by the truss-core sandwich when the intensity of loading is greater than about 1300 psi. This is explained by the fact that honeycomb core can effectively stabilize very thin facings but its contribution to the transfer of axial forces is not optimum.

Skin to Core Attachment

Despite the high efficiency and weight savings indicated for the several types of sandwich plate, its use has been limited by one major problem—attaching the facing sheets (skins) to the core material. This problem has been and is now the subject of wide investigation by both government and industry.

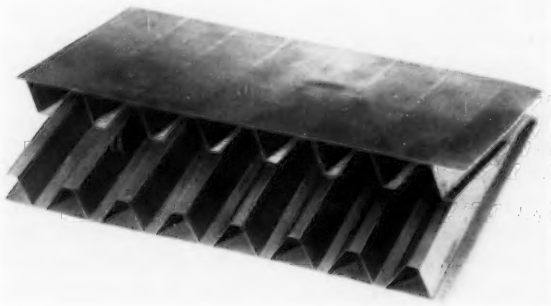
New Entry

One new development which shows promise is a truss-core type sandwich called Plyweb. It provides a reliable high-strength joint between the core elements and the face and may be manufactured easily at low cost.

The several major points which make it worth considering are:

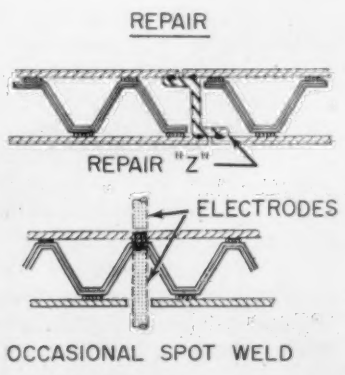
- Splice joints and fastenings can be made before sections are joined, eliminating blind fastenings.
- Damaged parts can be replaced without excessive weight penalty.
- Direct inspection of the core to face weld can be accomplished without special techniques or equipment.
- Compressive and bending loads can be carried without the core participating fully.
- Production can be effected by simply nesting the half shells then bonding.

This particular truss-core sandwich consists of two separate structural halves which, when joined, form a complete sandwich plate. The core elements are seam welded to the facing plates using standard mass production methods. The two



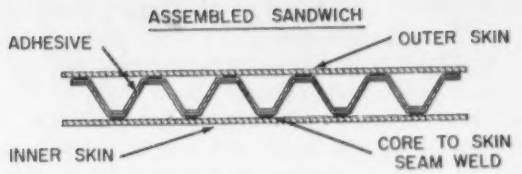
Sandwich facing is multiple seam welded to the truss core prior to the assembly of the sandwich. Inherent difficulties of skin to core sandwich bond are thus minimized.

Repair of components can be effected in several ways: "Z" member, or spot welding, weight penalty is not a serious factor in either case.

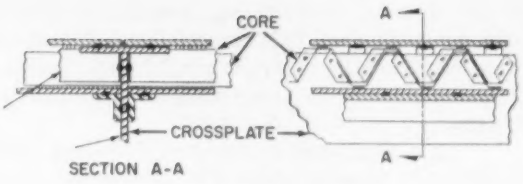


truss-core sandwich structures

continued



TYPICAL SPLICES AND CONNECTIONS



halves of this sandwich must be joined, this may be accomplished by bonding metallurgically, chemically or mechanically, depending on functional requirements. Chemical bonding appears desirable in structures for use at room or moderately elevated temperatures. At extremely high temperatures, an all welded sandwich is more desirable; in each case the cost of production is very low.

Joining

It is desirable to bond the entire mating surface when individual halves are joined. Because of the large bonding area, stresses imposed on the adhesive are not high.

For operating temperatures of 500°F, welding or brazing is more desirable. To determine the spacing of the spot welds it is necessary to consider the column action of the two halves acting separately and as a unit. It may be shown by calculation that the radius of gyration of one-half of the sandwich is 80 percent of that of the assembly, therefore if the unsupported length of the individual halves is less than 80 percent of the panel length of the entire sandwich plate, failure will not occur by separation. Of course this is not a desired type of bonding since the increased core stability experienced with continuous bonding does not exist.

WELDING can be done in two ways, spot or tack welding, and seam welding. Tack welding is accomplished by drilling small holes in predetermined areas and welding as shown in the accompanying illustrations.

Resistance welding is done on special welding machines of the type produced by Sciaky Bros., or Budd Manufacturing Co. Welding can be done at a rate of about 10 ft per sec.

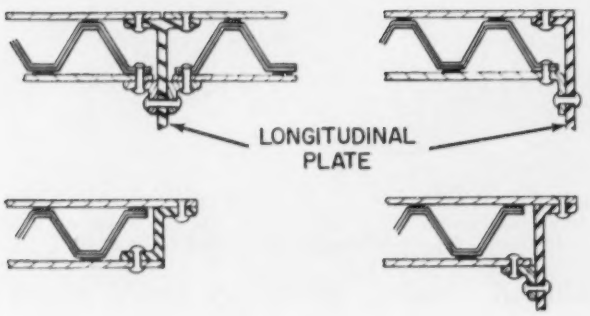
ADHESIVE BONDING has caused no great problems in joining the truss type sandwiches. Accepted methods of joining other types of sandwich structures have been satisfactory.

BRAZING is a growing art in sandwich construction, but has been used primarily to join the face to the core. This skin to core joining is done by welding in Plyweb. Brazing does not seem to offer any advantages in joining the individual sandwich halves. If operating temperatures are too high for adhesive bonding, welding is recommended.

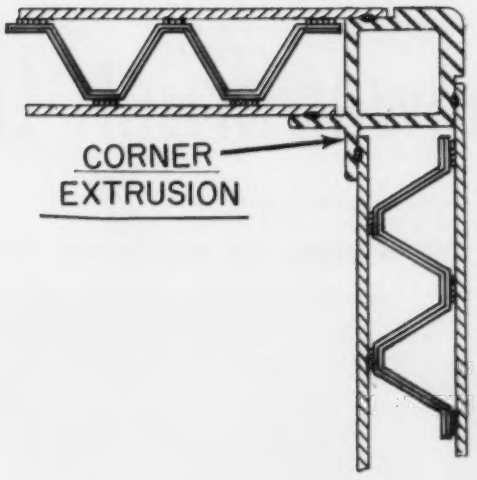
Optimum Design

The achievement of optimum design in truss-core sandwich is quite simple. It has been determined that the optimum geometry for axially loaded sandwich plates is very nearly one formed by equilateral triangles. The sheet thickness for the core should be approximately that of the faces. The design procedure is further demonstrated by the curves in Fig. 2. These curves were plotted for the design condition of axially loaded truss-core sandwich plates in stainless steel at 800°F and one-half hour exposure at this temperature.

It can be seen that the length of a panel (L), has as much influence upon the design as the load. In the case of a wing structure, this length might be the spanwise distance between ribs. For a particular design, several different values of (L) may be assumed in order to select that value which yields the most satisfactory overall design. The selected design is not necessarily the one which leads to the highest operating stress.



TYPICAL SPLICES AND CONNECTIONS
FOR PLYWEB SANDWICH

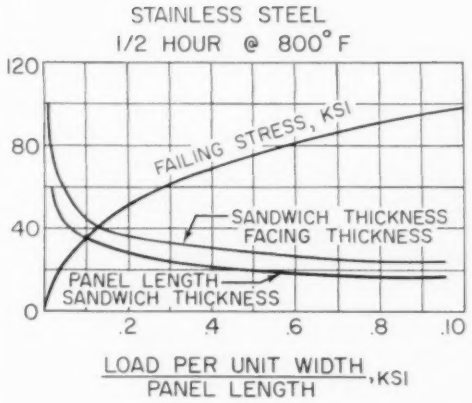


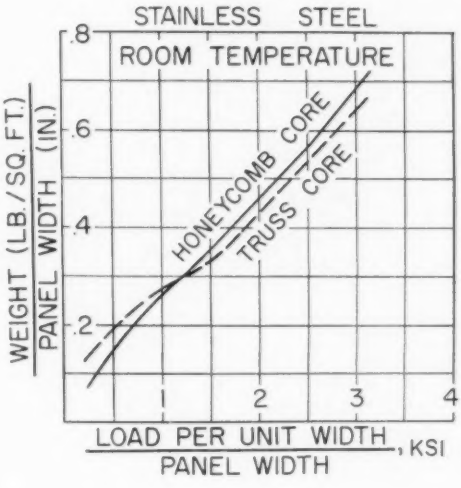
In plotting curves for a particular type sandwich it is necessary to know the geometry of cross-section of the sandwich and the stress-strain relationship of materials at environmental operating temperatures. Once such curves are prepared they will be sufficient to satisfy design conditions for most variations in panel load (P) and length (L).

Manufacturing — Attachment

This structural sandwich may be manufactured in a variety of materials such as stainless steel, titanium, aluminum, magnesium, fiberglas, or many combinations of materials that might be necessary to maintain structural integrity in a particular temperature range. Individual ducts that go to make up the truss core may be sealed and used to insulate the structure, to circulate coolants, or to preheat fuels and fluids.

In order to use high strength plates efficiently, attachments between the sandwich and its supporting structure must be minimum in weight. In addition, these attachments must be capable of transferring full loads between the sandwich and its supporting structure. During a series of tests at NACA it was found necessary to reinforce the ends of sandwich plates having honeycomb core. In tests of truss-core sandwich plates, no end reinforcement was necessary.





power-brush finishing

semi-automatic equipment removes burrs, blends tool and grinding marks without causing secondary sharp edges

by J. A. Kasnyik, engineer, Osborn Manufacturing Co.

More than half of the failures experienced in well designed jet engine parts are the result of stress concentrations and progressive fractures which occur at scratches, sharp edges, or burns. With continued repetition of stresses imposed by engine operation, microscopic cracks are propagated and the entire member may rupture if the crack is not detected.

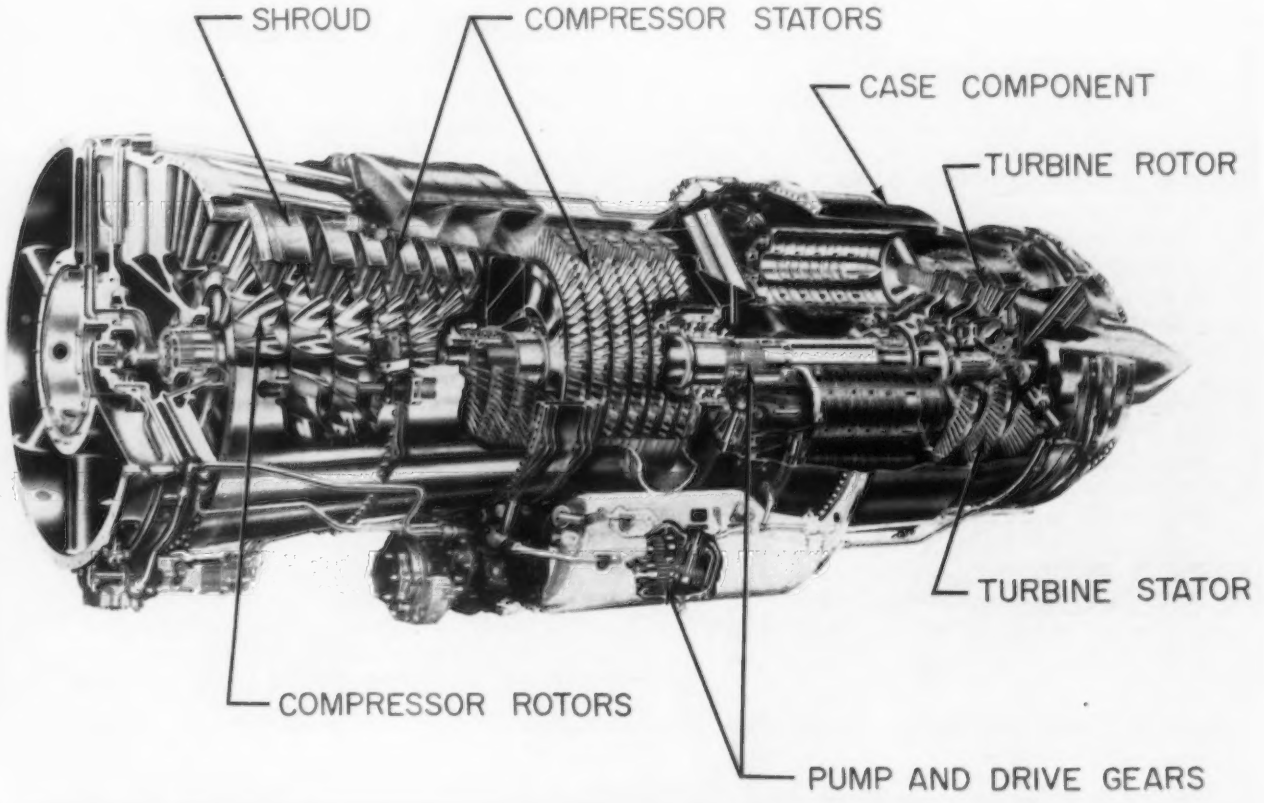
Data has been presented to show that a sharp corner or edge may reduce the endurance limits of a part as much as 50 percent. A distinct "V" notch, such as might be made with a hard tool, can reduce the endurance limit of a part as much as 60 percent.

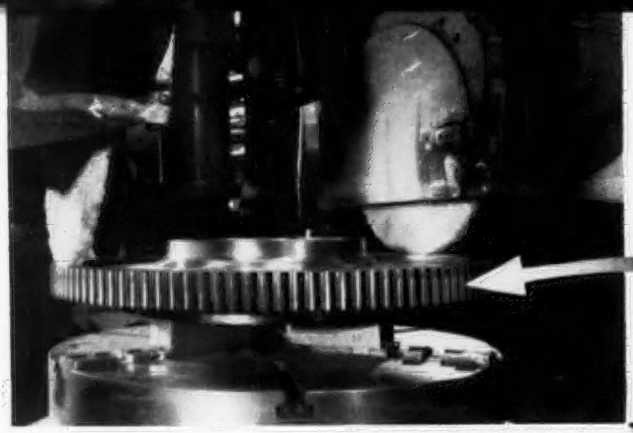
This has resulted in high standards for surface finishings on turbojet engine parts.

Hundreds of man hours were originally spent on tedious hand finishing and inspecting operations. The finishing department became a high cost operation, and a production bottleneck.

Recognizing the magnitude of the problem machine tool engineers teamed with aircraft engineering personnel to devise power brush finishing methods capable of eliminating the slow, costly

A jet engine contains many parts that need quality surface workmanship. Power brushing is a good method for such finishing; it removes burrs and gives excellent surface juncture blending.





Power brush finishing is done on the two edges of the "christmas tree" and the O.D. of a turbine discs.

With hand finishing methods an operator turned out two pieces a day. New method requires only 12 min for the same job.

hand finishing processes.

Advantages

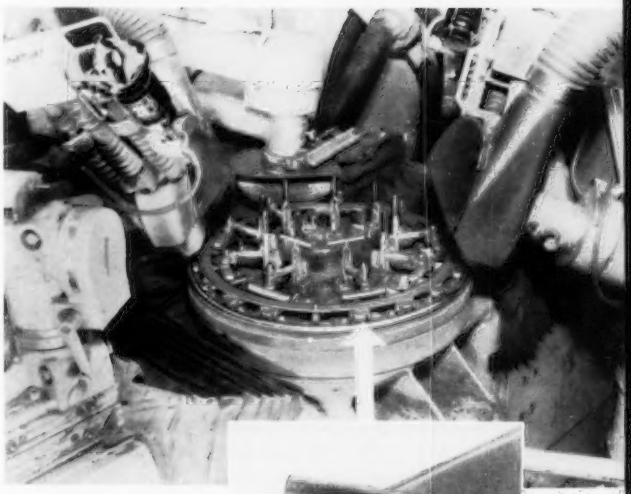
Power brush finishing offers the following advantages:

- Removes burrs completely and does not produce a secondary burr by creating two sharp edges on the machined surface.
- Produces a uniform finish with a surface refinement of 8 to 10 RMS simultaneous with burr removal.
- Increases production rates and simultaneously decreases costs.
- Blends tool and grinding marks and helps reduce the number of stress focuses for failures by reducing stress concentration.

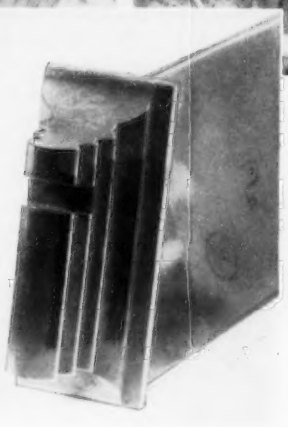
The blending of sharp markings is a prime consideration, and smoothness may or may not be required. The smoothness imparted by power brush finishing does assist in reducing friction, scratching, and seizing; and reduces contamination of lubricating fluids by metal particles.

The action of power brush finishing is that of blending surface irregularities as well as removing burrs. Surface analyzer readings may show surface roughness of 24 to 35 micro-inches before brushing and be reduced to 4 to 7 micro-inches after brushing.

This method of surface finishing has long been accepted in other industries. However, special machinery was needed to provide the precision surfaces of jet engine components. Osborn Manufacturing Company has been instrumental in providing the aircraft industry with machinery that has this capability.



Turbine blades (18) are set in a special fixture on the turn table.



Fixture consists of a nest for the blade that keeps the root end protruding and a clamp for holding the blade in place.

Successful Applications

Power brush finishing is used widely in jet engine manufacturing today. Some of the applications are listed in the following table.

power-brush finishing continued

ACCESSORIES

Pump gears, J-46, J-47, J-57, J-65, J-71, J-75, J-79.

Drive gears, J-46, J-47, J-57, J-65, J-71, J-75, J-79.

Bearing lock plates, J-65, J-71.

COMPRESSOR STATORS

Outer shroud, Stages 1 to 4, and 16-J on J-75.

Inner shroud, Stages 1 to 16 on J-57, J-75.

COMPRESSOR ROTORS

Compressor disc, J-46, J-57, J-65, J-71, J-79.

TURBINE ROTORS

Turbine wheel, J-47, J-57, J-65, J-71, J-75, J-79.

Bucket root sections, J-71.

TURBINE STATORS

Turbine nose case, J-57, J-75.

Nozzle case spacer, J-57, J-75.

Machine Description

The Brushamatic 51 Series machines utilize two types of interchangeable brushing head combinations, which are used in conjunction with one vertical spindle rotating work table.

The two brushing heads are designated the "L" head and the "O" head.

The maximum diameter of a part that can be processed is determined by the type head used. When the "L" head is used, the maximum diameter is generally limited to 48 in., because the head is attached directly to the work table. However, special provisions have been made to accommodate larger parts by modifying the machine.

When "O" heads are used there is no definite limitation on size imposed by the brush arrangement because the heads are not attached to the work table. The limiting factor is the 2000 lb capacity of the work table.

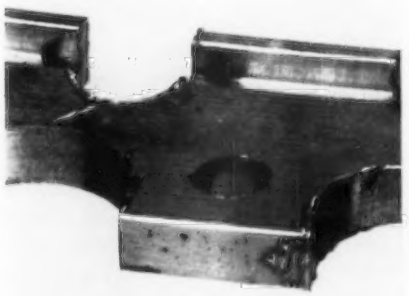
When a combination of "O" and "L" heads are used the part is limited to 48 in. in dia, if no modifications are made to the machine.

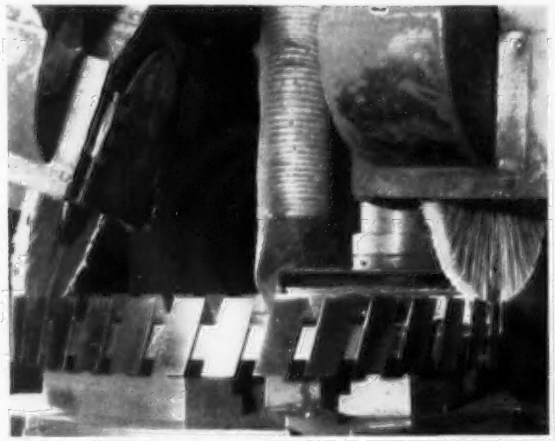
The operation of the power brush finishing machines has been easily learned. In production the operator places the part on the machine turn table, starts the machine, and after the completion of the brushing cycle removes the part. The table rotates the part at a predetermined rpm. A preset timer retracts the brushes and the motion is stopped until actuated by the operator. The operator has little to do but load, unload, and make adjustments for brush wear.

Specifics

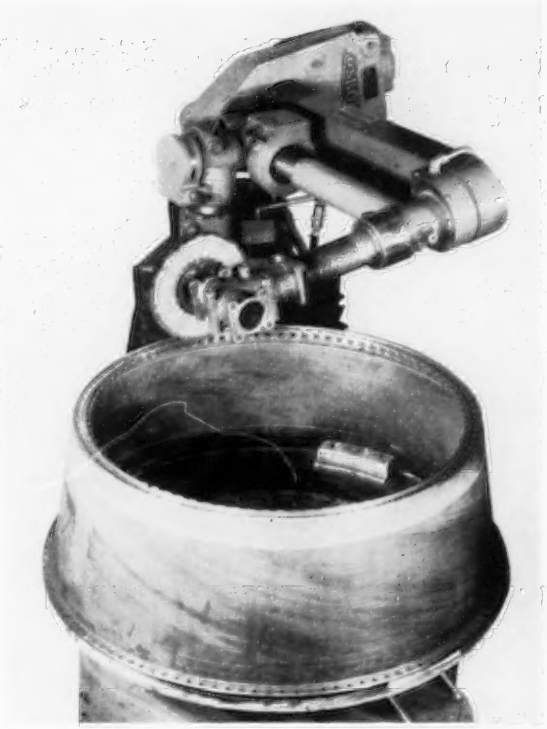
On turbine discs, the brushes finish the two edges of the "fir tree" and the O.D. The brushes are prepositioned so they cross the sides of the "fir tree" at the proper angle. A wider faced brush is used on the O.D. Entire cycle time is about 4 min per side.

Savings of over 130 hr per jet engine were realized by one manufacturer in processing compressor discs with a similar arrangement. Prior

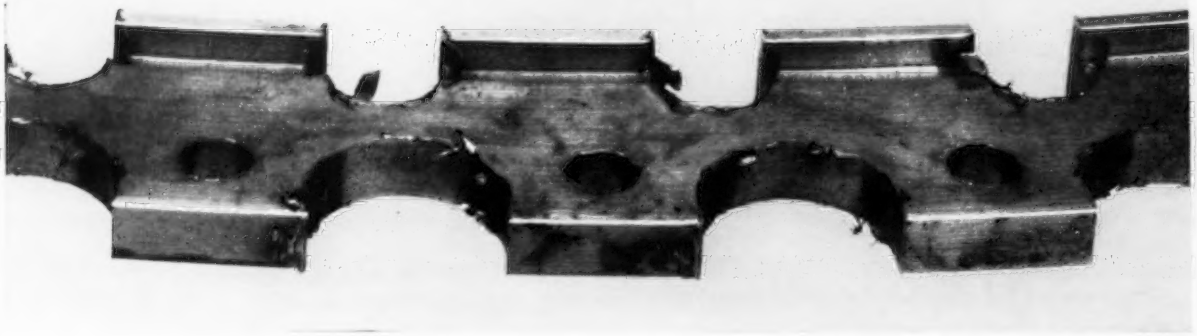




For compressor discs, one brushing head does the I.D. of the "tang." The other "O" head does the top of the "tang," while an "L" head (not visible) does the O.D.

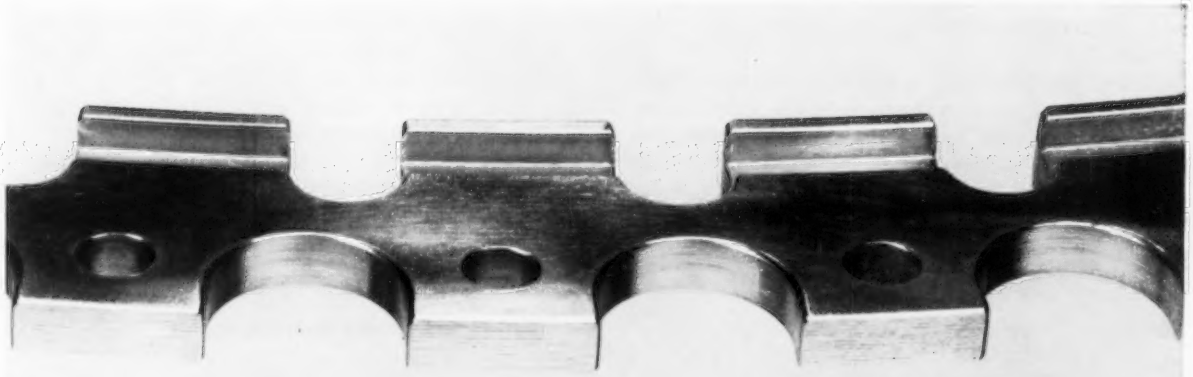


A set up has been developed for brush finishing jet engine case components. Quality of the finished casing ring is such that no further finishing is needed.



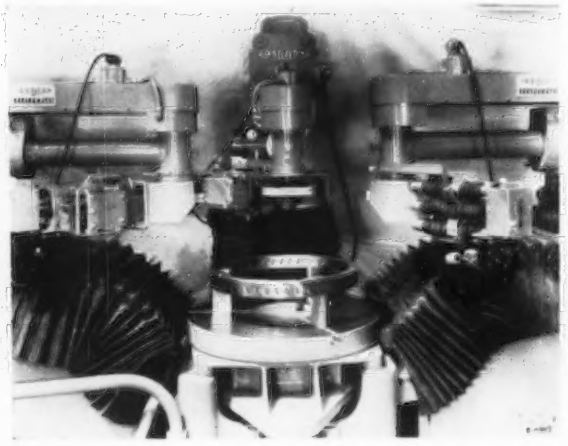
Casing ring before power brush finishing.

Casing ring after power brush finishing.

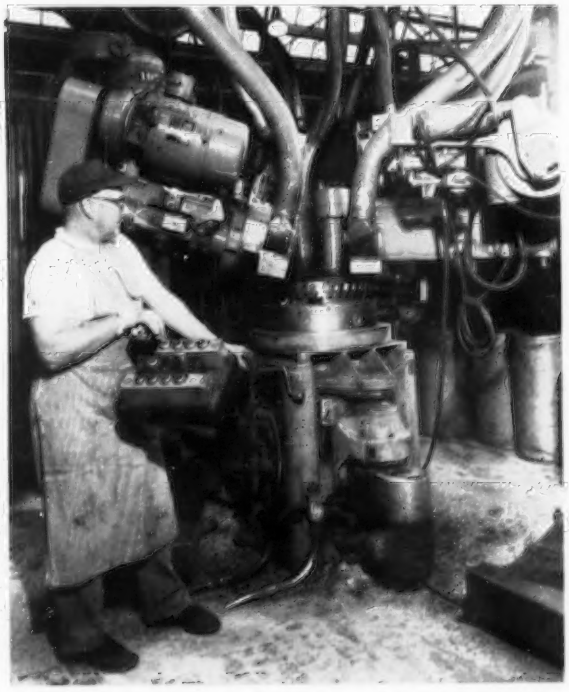


power-brush finishing

continued



Jet engine shrouds are power brush finished on a machine with "L" heads. The part is placed on a rotary work table, and prepositioned brushes finish the "banana slots."



With most power brush finishing machines the operator has little to do but load and unload the machine. Control console has provisions to check brush wear.

to power brush finishing, eight hours were consumed per disc, now each component is brushed to a 10 micro-inch finish in 42 min.

One brushing head is set at an angle to finish the inside diameter of the "tang." The "O" head finishes the top of the "tang," while the "L" head does the O.D. The brush pressure is preset, a meter tells the operator when brush wear has disturbed the preset pressure. Through a simple adjustment on the control panel dial, pressure readjustment may be reset by the operator.

Turbine Blades

To hand finish the hundreds of turbine blades that go into each turbojet engine was especially time consuming and expensive. Using a 51-3L power brush finishing machine, blades can be mass precision-finished quickly and economically.

Eighteen blades are set in a special holding fixture attached to the turn table. This fixture consists of a nest for the blade that keeps the root end protruding and a clamping device for holding the blade in place during the brushing cycle.

Two "L" heads brush the blade roots, while a third "L" head brushes the pin slot of the blade. All minute burrs on the root end are removed and surface junctures are blended. Results are uniform at a high production rate. The operator simply loads and unloads the machine.

Case Components

An interesting power brush finishing set up is being developed for finishing jet engine case components.

The machine in use consists of a turn table with three "L" heads attached. A special holding fixture positions the housing. One breech first finishes the top of the ring, removing burrs and blending surface junctures, while the other two work on other areas. The housing is then turned over manually by the operator. The brushing heads automatically position the fiber brushes to finish the inner surface of the ring. Quality of the finished ring has been such that no further finishing operations are needed.

In a short period of less than five years, power brush finishing has gained wide acceptance. It provides the means of achieving uniform surface refinement and edge contouring on engine components of a quality and quantity unobtainable by any former method.

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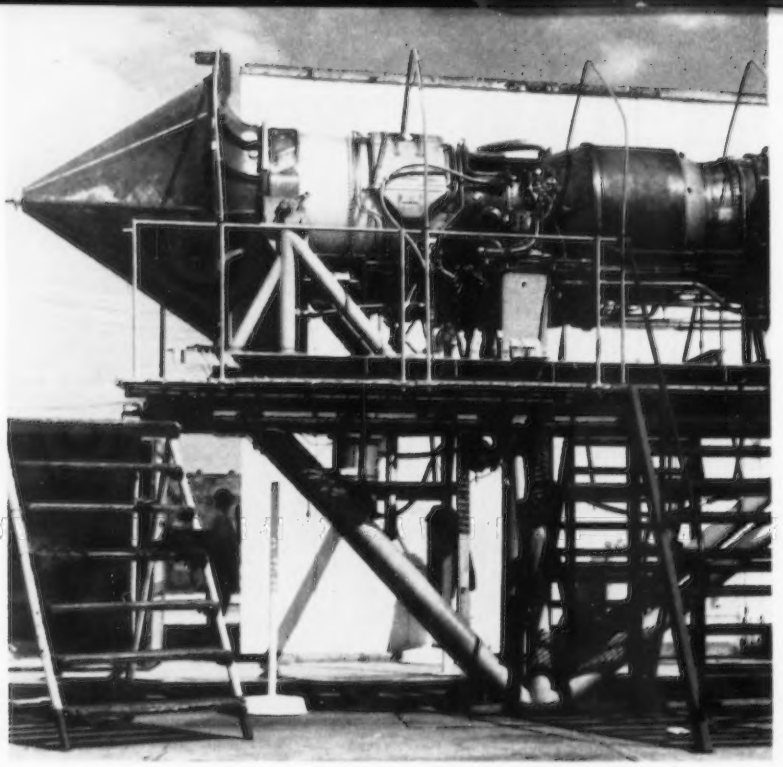


multiple shrouds reduce normal noise generation by breaking up exhaust stream

jet engine noise suppressor

An exhaust noise suppressor for use in testing jet engines recently underwent successful evaluation tests at Republic Aviation Corp. The Multi-Jet is manufactured by Industrial Acoustics Co., under license from United Aircraft Corp. It represents a major stride toward noise abatement.

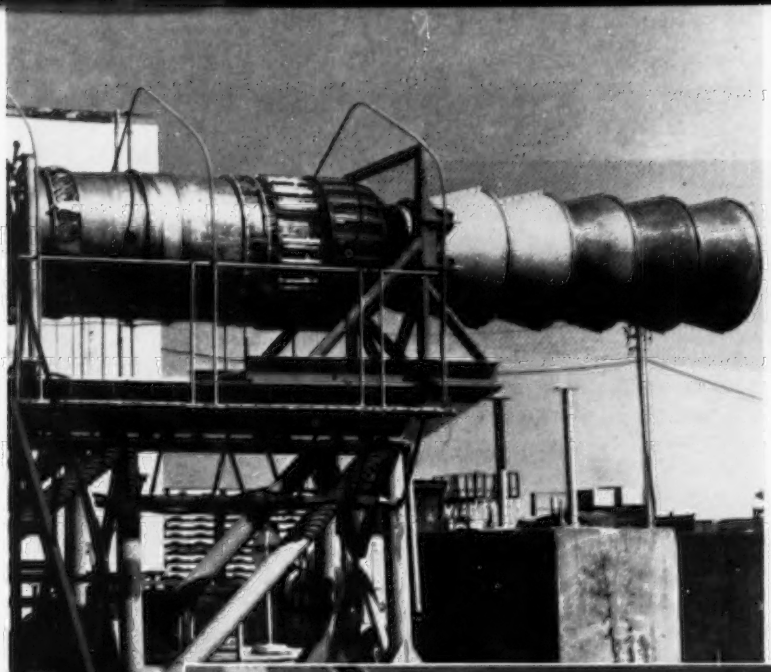
Operation

The acoustical principle of this device is expressed more accurately by the term *suppression* than that of *silencing*. Multi-Jet reduces jet engine exhaust noise by preventing its normal generation rather than attempting to silence the noise after it has been generated. This is accomplished by breaking up the exhaust stream, by passing it through a perforated duct, then bleeding it off through a succession of concentric conical shrouds. The noise reduction achieved by the system is at all angles on lower and middle frequencies where ear plugs and natural attenuation with distance are least effective.

The graph shows reduction of jet engine exhaust noise to a residual spectrum tolerable to the human ear. Although this graph directly reflects the data obtained from J57 tests, the results of tests with the J47 and the J75 engines indicated similar results.

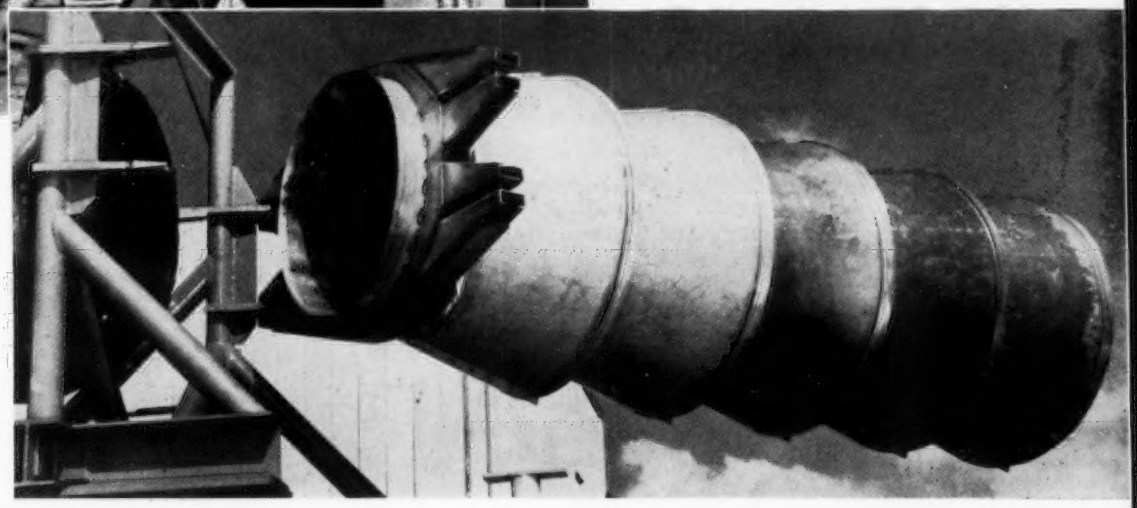
Applications

This suppressor is being used in ground testing of Air Force's supersonic fighter-bomber,

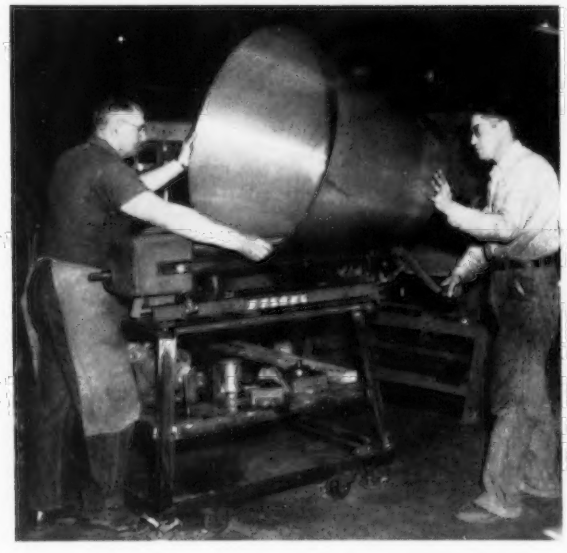


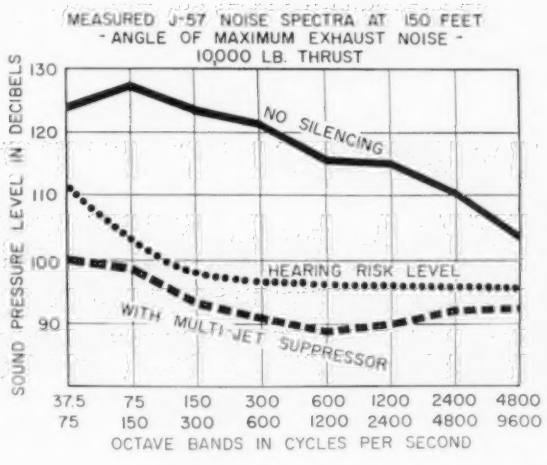
Multi-Jet suppressor shown mounted on J75 permanent type of test stand, at Republic Aviation Corp., Farmingdale, N. Y.

Below:
Hinged mounting adapter permits swiveling of suppressor for easy disengagement from engine.



Roll-forming of sheet stock into shroud.





jet engine noise suppressor

continued

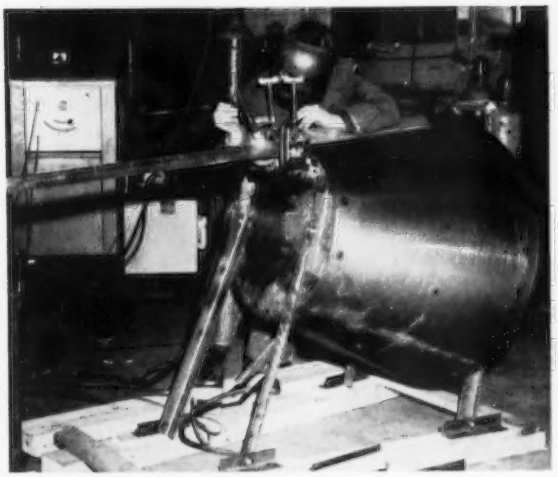
the Republic F-105 Thunderchief, powered by a Pratt and Whitney J75, which develops 15,000 lb of thrust without afterburning.

The relatively light weight (400 lb) of this unit lends itself to portability and versatility of installation arrangement. It may be mounted on a trailer and maneuvered into position for ground run-ups of jet airliners or military aircraft. Currently, an installation of the suppressor directly on the jet engine nacelle, for ground-run purposes, is also under consideration. Five other silencers, developed jointly by Industrial Acoustics Co. and Republic, have been in operation in the ground testing of the F-84F Thunderstreak and the RF-84F Thunderflash.

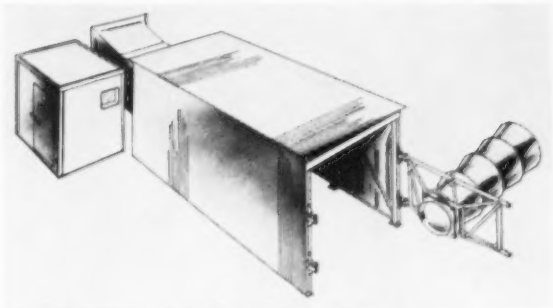
Simplicity and Durability

The durability of the Multi-Jet suppressor is derived from the simplicity of its structure. A recent inspection of such a unit, after it had accumulated over 50 hours of operation with a J-75 engine, revealed no signs of deterioration. Although not intended to compete with the more permanent type of installation of the Dura-Stack, experience to date indicates Multi-Jet units will serve their function for several hundred hours without necessitating major maintenance.

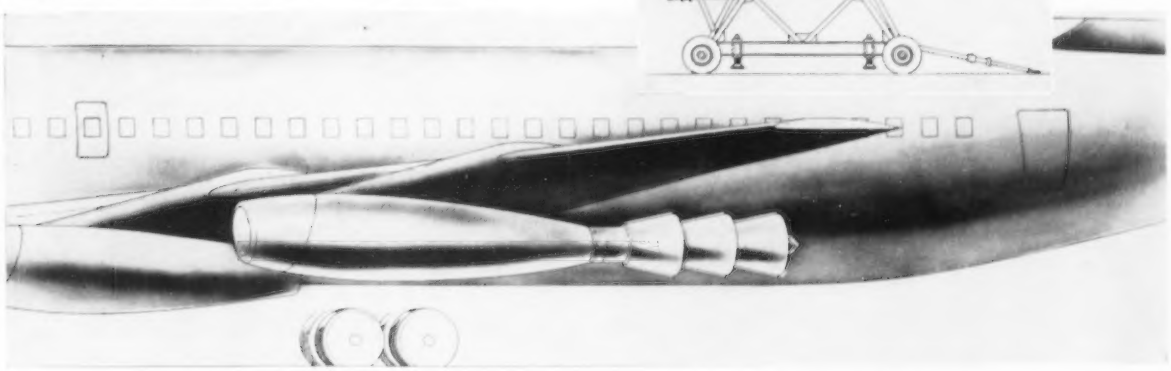
To withstand the extended exposure to the high-velocity blast at nearly 1200°F, the Nimonic family of steels has been used in thicknesses ranging from 22 to 12 gage.



Assembly by shielded-arc welding.

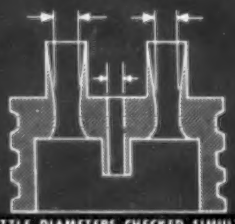


Sheltered field-testing arrangement for engines showing suppressor in hinged-open position.



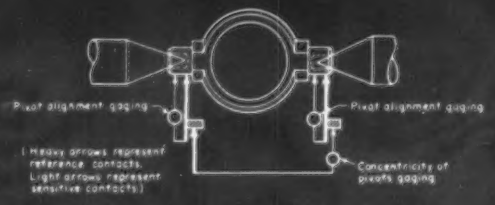
Vertical adaptation for limited ground space. Suggested installation for ground run-up operations.

Precision here



FOUR NOZZLE DIAMETERS CHECKED SIMULTANEOUSLY

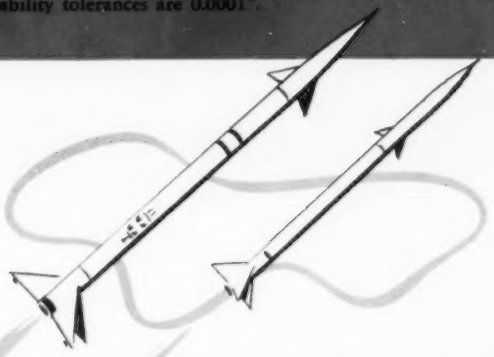
Multi-unit air gage (Dimensionair) uses four contact-type air plugs to check diameter of land in nozzles (tolerance ±.0005"). Regular air plug checks centrally located bore (tolerance ±.0002"). Nozzle assemblies and masters shown on gage platform.


Pivot alignment gaging
Pivot alignment gaging
(Heavy arrows represent reference contacts. Light arrows represent sensitive contacts)
Concentricity of pivots gaging

GIMBAL CONCENTRICITY AND ALIGNMENT CHECKED

Triple-unit Dimensionair Air Gage simultaneously checks alignment of each pivot with centerline of gimbal, and concentricity of one pivot with the other. Has precision centering stocks which enable gimbal to be quickly and accurately positioned for gaging. Acceptability tolerances are 0.0001".

for performance out yonder



Once an operational missile is launched, it is beyond recall. The precision of its parts will largely determine its success. Hence, its parts and components need a lot of down-to-earth small-figure planning, many times involving production tolerances of .000010", or smaller. The responsibility for maintaining this high precision requires a degree of dimensional control which can be entrusted only to gages whose qualifications have been thoroughly tested and proved.

Federal's long experience in furnishing gages and gaging programs for missiles is your assurance of dependable performance. Our special engineering skill and firsthand knowledge of missile problems have paid off for many producers of parts and components, and they can help you, too.

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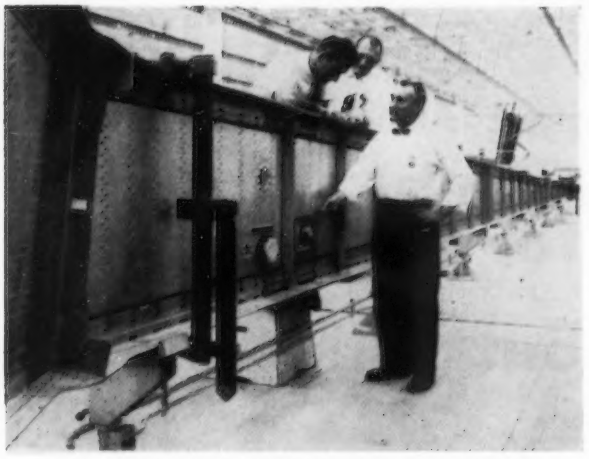
DC-8 moves into production

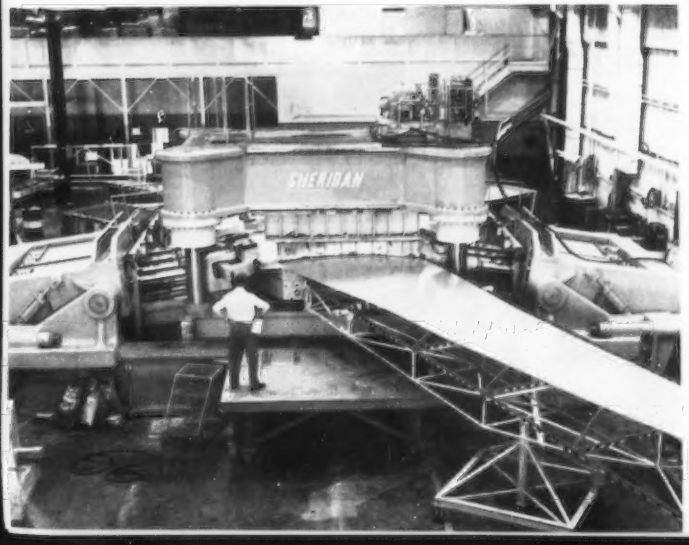
Douglas' proven design and manufacturing concepts evident in Jetliner planning shows complete company confidence in new aircraft

by Robert McLarren



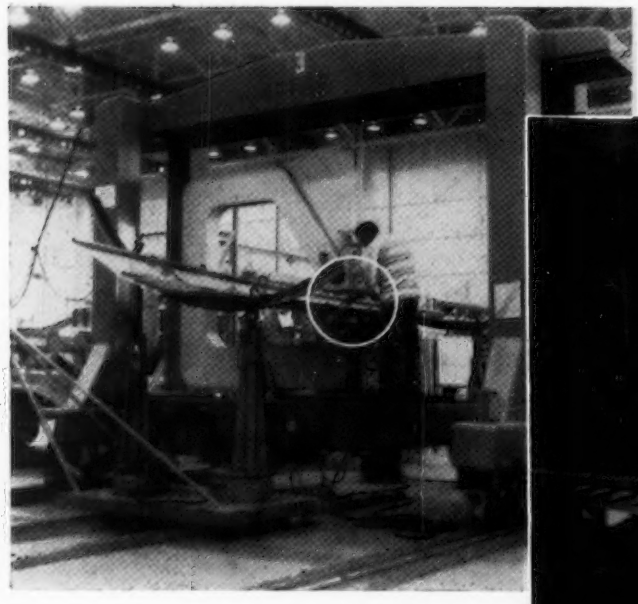
Main wing spar is 7075 sheet web and forged cap strips. Note fuel sealant (black lines) applied by hand during spar assembly operation.

World's largest stretch press, this huge Sheridan stretch-forms complex airfoil shape into DC-8 wing root skin panels.

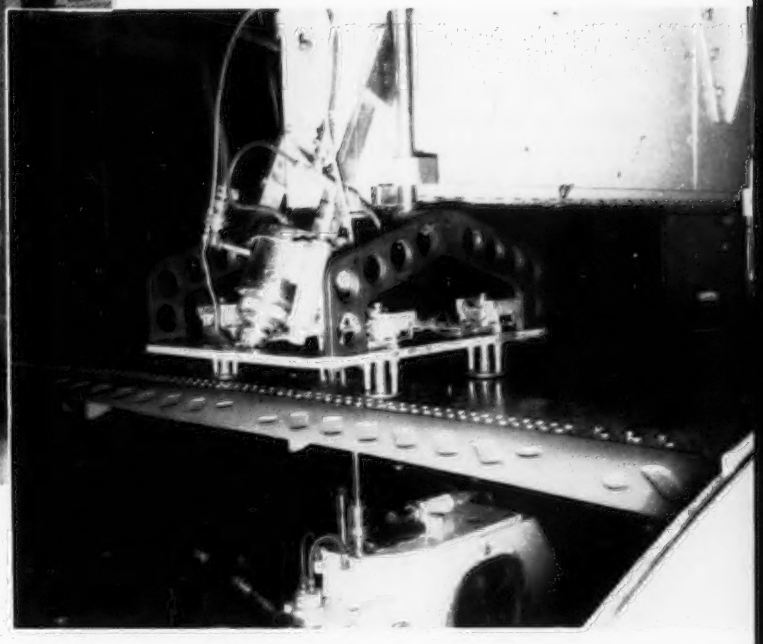


One of the world's greatest expressions of faith in a single new product is embodied in the Douglas DC-8 Jetliner, whose development and production program will constitute a $1 billion investment on the day the first airplane is delivered. Yet, this display of faith in an untried aircraft comes from Douglas Aircraft Co., Inc., renowned for its technical and financial conservatism.

The decision to commit the resource limits of the company to the DC-8 came in mid-1956, when the Pratt and Whitney J75 engine, now



Manco Crispin automatic riveter moves machine past work held in fixtures at either end. Yoke (inset) moves upward to clamp work, upset rivet and shave excess rivet material to close tolerance.



certified as the JT-4, became available for commercial use.

First flight of the DC-8 scheduled for May, 1958, will culminate 12 years of study of every facet of the jet transport problem, from a hydraulic valve to operating costs for a Nairobi-Khartoum route segment. There is to be no "prototype" airplane: the first plane will take to the air while production airplane number 20 is already moving down the line, and present schedules call for airplane number 39 to be on the assembly line before the design is certificated by the Civil Aeronautics Administration.

Design Philosophy

Douglas has shunned many dramatic and new techniques in the structural design of the DC-8. No extensive use has been made of such developments as integrally-stiffened sheet, chemical milling or plastic parts; instead, the proven conventional methods of construction used in the successful DC-6/7 series aircraft are carried over.

High fatigue life has been the major structural quality sought for in the design of the DC-8. Douglas does not feel that enough experience has been accumulated on the fatigue qualities of thick sheets and integrally-milled sheet stiffeners to warrant their uninhibited use.

Douglas is, in effect, producing two separate airplanes in the DC-8; the standard domestic version, and the intercontinental model. The latter features increased skin gauges throughout to accommodate the 8.5 per cent increment in gross weight. Both versions utilize the same tooling.

Experience with the DC-6/7 series has convinced Douglas that a lighter airplane results when an existing air-frame is "stretched" to heavier gross weights, than when detail design is "shrunk" to a lighter-weight model.

Wing

Major research and development attention was devoted to the wing root design, both aerodynamically and structurally. Conventional bending loads on straight wings become torsional loads on swept-wing roots, and this, in combination with the increased gust loading anticipated at the

DC-8 moves into production

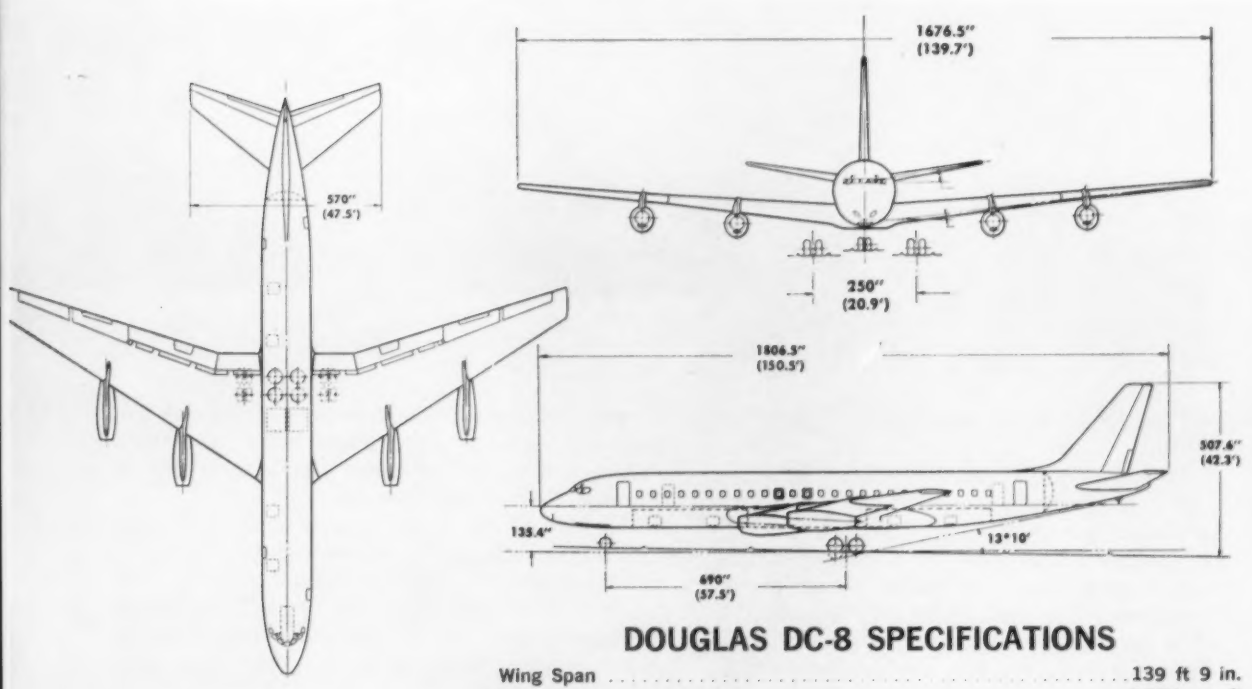
continued

altitudes and speeds to be experienced in service, brings fatigue life to its critical values in the wing root.

The wing is fabricated entirely of 7075 aluminum alloy containing 1.6 copper, 2.5 manganese, 5.6 zinc and 0.3 chromium percentages. Wing skins are very large plate carried directly into the airplane centerline splice in a single, integral unit. Elimination of separate wing panels saves about 800 lb and greatly improves fatigue resistance. Wing plating is roll-tapered from 0.230 in. at the root to 0.064 in. at the tip.

These tapered plates (largest is 34 ft long x 14 ft wide) are shipped in refrigerated cars at —30°F to prevent metal aging in transit. They are stored under refrigeration at the Douglas plant until ready for use, at which time they are removed by a special vacuum hoist. Root skins, which contain the dihedral angle, are placed in a Pacific 500 power brake to impart the required bend.

Following forming, on a four directional Sheridan stretch press, the edges of the skin are trimmed and the part is oven aged to the T6 condition. The plates are then cleaned, surface treated and hoisted to the appropriate assembly jig.



DOUGLAS DC-8 SPECIFICATIONS

Wing Span	139 ft 9 in.
Wing Area	2,758 sq ft
Length	150 ft 6 in.
Height	42 ft 4 in.
Wing Sweep (25 per cent chord)	30 deg
No. of passengers	144
Cargo	14,150 lb

WEIGHTS AND PERFORMANCE

	Domestic		Intercontinental	
Engines	J57	J75	J75	Conway
Empty Weight	115,839 lb	118,265 lb	120,737 lb	117,423 lb
Fuel Capacity	17,600 gal	17,600 gal	21,615 gal	21,615 gal
Payload	33,620 lb	33,620 lb	35,930 lb	35,930 lb
Gross Weight	265,000 lb	265,000 lb	287,500 lb	287,500 lb
Cruise Speed[1]	561 mph	586 mph	586 mph	590 mph
Takeoff Distance[2]	9,860 ft	7,300 ft	8,760 ft	8,870 ft
Range[3]	2,040 mi	3,470 mi	3,070 mi	3,330 mi

Note: (1) At 30,000 ft, 220,000 lb weight; (2) CAA field length at maximum gross weight; (3) At 6,500 ft CAA field length.

Fuselage nose sections are pressure-tested separately. Main fuselage line moves past this position where nose section is mated.

The wing box beam retains Douglas' traditional three-spar arrangement and comprises a complete, integral fuel tank. Spars have conventional sheet webs with riveted vertical stiffeners and 78ST forged spar caps machined all over.

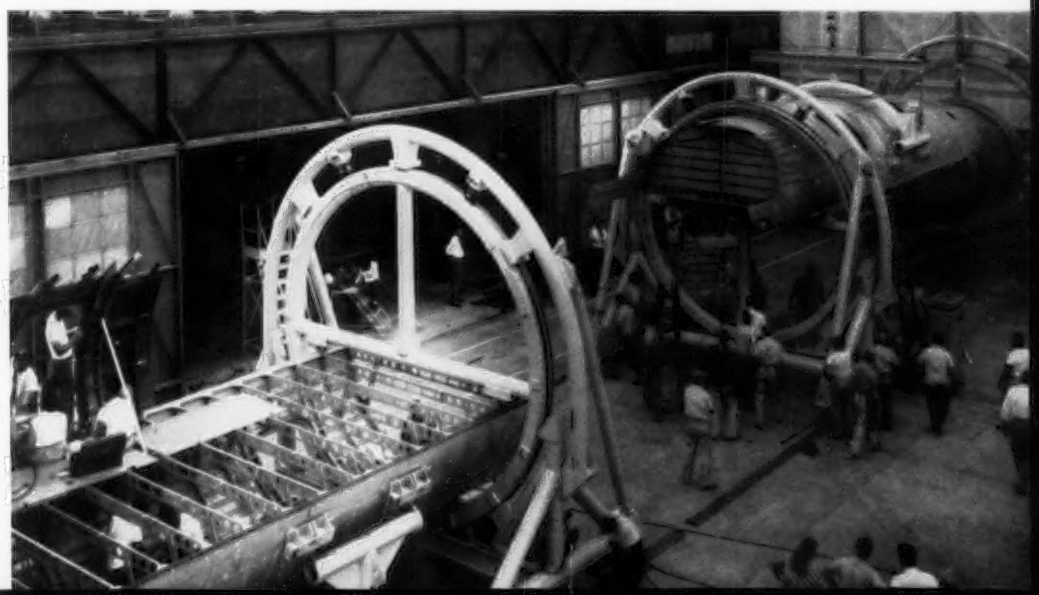
Wing ribs are of formed 75S sheet with tab segments along their periphery. These tabs are tied into the skins by clips milled from 75S extrusions. The wing box beam is divided into four separate tank sections separated by solid rib bulkheads. When the two wing panels are joined, a ninth tank is created at the wing junction.

Sealing Fuel Tanks

The wing halves joined at the centerline thus create a complete integral wing. After many years of experience, Douglas has minimized faying surface sealing in favor of hand-filleting of sealing compound. During the wing tank assembly operation, itemized areas are hand filleted with Products Research PR-1422 Thiokol sealing compound. This brown paste cures in about four hours at room temperature.

The completed wing is moved to a separate tank sealing building where a 0.001 in. thickness of EC-766 sealant is applied to internal surfaces of all wing tanks.

The wing is installed on tiltable platform and the tank compartments are partially with the synthetic rubber-base sealant. Two hydraulic cylinders, with 14 in. dia. and seven-ft stroke then tilt the wing to about 10 deg each side of the horizontal to insure coating the complete tank interior. The sealant is then pumped out and hot air is circulated through the wing interior to cure the sealant. The wing is then given the



Giant turning rings rotate fuselage lower panels from working position (right) to installation position (left). External fittings (lower left) ultimately support entire fuselage before mating to wing.

DC-8 moves into production

continued

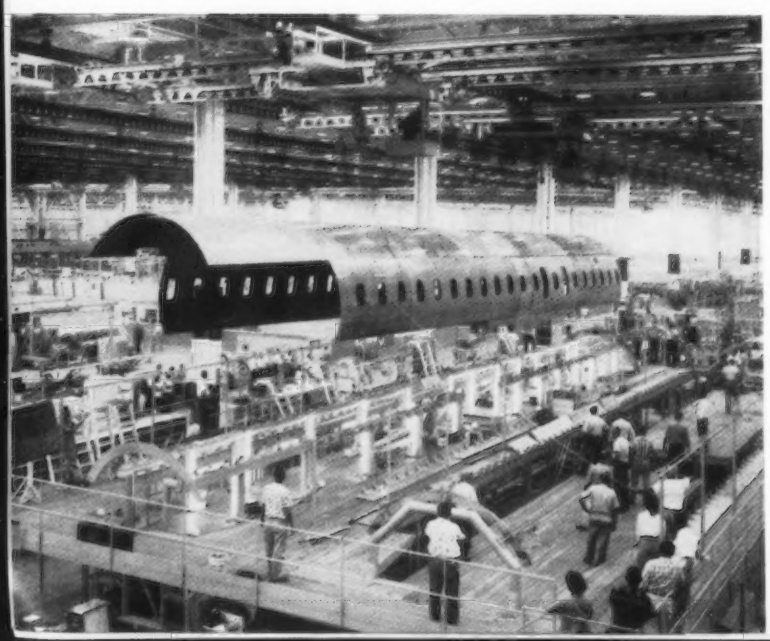
"soap-bubble" final check to detect any leaks.

Fuselage

The DC-8 fuselage incorporates two different structural entities determined by the jet engine noise problem. In flight, jet engine noise is not audible forward of the tailpipe; aft of the tailpipe the noise level is high. Douglas attacked the problem at first by using increasing thicknesses of sound-absorbent materials in the fuselage walls. In a pioneering decision, Douglas structural engineers raised the question: "Since simply mass of material—regardless of its nature —is being sought, why not use metal?" Extensive tests proved the simple, but radical, concept an ideal solution to the problem, with the result that the rear portion of the DC-8 fuselage is lined with closely-spaced longitudinal stiffeners of a flattened hat-section. This also proved desirable in light of the substantial tail maneuvering loads imposed on this region, which tend to promote fatigue failure. The aft fuselage is covered with 7075ST skin, and the forward area, which is supported by conventionally-spaced stiffeners, is covered with 2014ST skin. The stress level in the aft fuselage is only about one-half that in the forward portion. Skin gauges in the forward portion are typically 0.050 in., those in the aft section typically 0.080 in.; tail carrying the heavier loads.

The problem of fatigue resistance in pressurized fuselages has been met by Douglas through the use of "stop rip doublers" (thin sheets of titanium) placed between the fuselage frames and the adjacent skin. Extensive tests have demonstrated that a fuselage skin crack, or rip, will not propagate past the edge of one of these titanium doublers. The DC-8 fuselage is composed of a main upper segment, and two lower fuselage assemblies. These lower fuselage sections are assembled in an inverted position for ease of riveting. Upon completion, they are mounted in huge turning rings. A single control over several synchronized motors rotates them into the complete fuselage assembly jig.

The upper fuselage is built up on stretch-formed, rolled or extruded lazy "Z" transverse frames, spaced on 20 in. centers, and flush riveted in a new type fastening machine. With this machine, the panel to be riveted is held stationary and the riveter is moved along the panel, thereby requiring only a little more floor space than that occupied by the panel. A single operator controls the placement of the riveting yoke over the desired spot, the drilling of the hole, the insertion and upsetting of the rivet and the milling of the driven head flush with the skin.



Complete upper fuselage assembly is hoisted from jig and transported across factory to lower fuselage mating jig. Note complete overhead railway system throughout bay.

Fuselage is hoisted in air and positioned over wing for mating operation as first step in final assembly bay. Unit moves down tracks picking up internal installations.

The completed upper fuselage is then hoisted into place over the two lower sections in the mating jib and the entire fuselage is riveted together.

The fuselage nose is built as a separate assembly to facilitate complex controls installation. The nose assembly is built in three major sections, a lower nose section, an upper nose section and a cockpit enclosure section. Material is 0.050 in. 2014ST throughout, with the exception of a 0.100 in. panel above the cockpit.

The main fuselage line moves along until it reaches the nose subassembly area, at which point the nose is joined to the fuselage. The completed fuselage then moves over to a new track and rearward the length of the building picking up installations.

Final Assembly Bay

Next, the fuselage is moved into the final assembly bay. The wing from the tank seal building is brought to the final assembly bay at this point and the fuselage is hoisted up and lowered onto the wing for mating. The completed wing-fuselage assembly then is moved along the bay, picking up installations, until it reaches the end of the building, where it is rolled outdoors where a fuselage pressure test is performed. The cabin is checked to a specification leakage rate at 12 psi to insure performance at normal operating pressure of 8.77 psi.

Following the pressure check, the unit is moved back to the final assembly bay, to receive its empennage. This is assembled as an integral unit and contains extensive laminated plastic panels for VHF, HF and VOR flush antennae.

The elevators are cable-controlled and employ spring control tabs for aerodynamic boost. The rudder is power controlled with hydraulic pressure but also has a mechanical control in case hydraulc failure occurs.

Last major units to be joined to the airplane are the powerplants, which are delivered complete by Ryan Aeronautical Co.

After leaving the final assembly bay, the completed airplane is towed to the paint shop and painted. It then moves to an outdoor line where pick-up items and electronics checkout are accomplished. The completed DC-8 is then towed to the airport to begin its flight checkout program.

Division Coordination

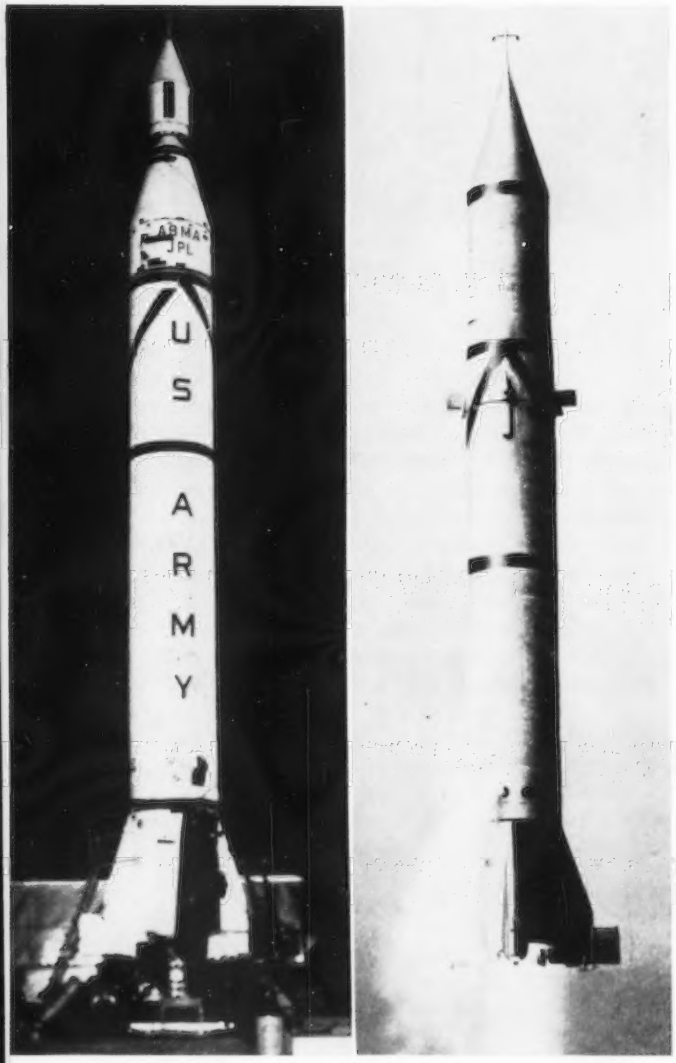
The DC-8 was designed and engineered at the Santa Monica Division of Douglas Aircraft Co. and this division retains engineering responsibility for the airplane. The aircraft is being manufactured in the new $20 million plant site of the Long Beach Division where a 10,000 ft runway will soon be available for testing. The runway length at Santa Monica is inadequate for the DC-8.

This results in engineering and production responsibility for a major aircraft being located 31 mi apart. No difficulties have been experienced in the coordination of the program and many participants point to the separation as advantageous.

hybrid Jupiter C

designed around existing hardware of Redstone and Sergeant missiles

by S. Peter Kaprielyan



Jupiter-C shown poised with re-entry nose cone vehicle similar to spin-launcher assembly utilized for the second, third, and fourth stages of Explorer.

The Redstone, predecessor of the Jupiter series became experimental test-bed for improved equipment.

Installing Explorer on spin-launcher pod. Strips of zirconium oxide on nose cone served to stabilize temperature of instrument capsule.

It may be some time before we do anything that may match the psychological impact of Sputnicks I and II, but the implications of the successful firing of the Explorer into orbit on January 31 were unequivocal. It was a first answer to the challenge made last Fall. Secondly, it has served as justifying evidence for the contentions of the "let's do it now, with what we have" school.

We now have an orbiting pioneer which was pushed into space by means of an aggregate of equipment existing for some time. The phrase "existing equipment" however tends to oversimplify the Explorer project from several respects. First, it was accomplished in a relatively short time; second, existing equipment was to be modified to suit the purpose; and third, programming the sequence of operation for the four stages, involving some 17 individual rockets, was also no mean task.

The lineage of the now twice-famous Jupiter-C includes such notables as the Jupiter IRBM, the Redstone, and a scaled-down adaptation of Thiokol Sergeant's solid propellant which was used in the second, third, and fourth stages.

There exists a definite "blood relationship" between the Redstone, the Jupiter IRBM, and the Jupiter-C missiles. All three have been produced by the Army Ballistic Missile Agency, Red-

Close-up of Explorer nose cone and shell before installation of instrumentation.

COMPARATIVE DATA

JUPITER IRBM

range: 1200 to 1500 mi
length: 60 ft (est)
diam: 8 ft (est)
thrust: 135,000 to 150,000 lb
weight: 100,000 lb (est.)
powerplant: North American Rocketdyne
propellant: kerosene—LOX

REDSTONE

range: 200 to 300 mi
length: 63 ft (operational)
diam: 5 ft 10 in.
span of fins: 12 ft
thrust: 75,000 lb
weight: 40.000 lb
powerplant: North American Rocketdyne
propellant: alcohol—LOX

JUPITER-C

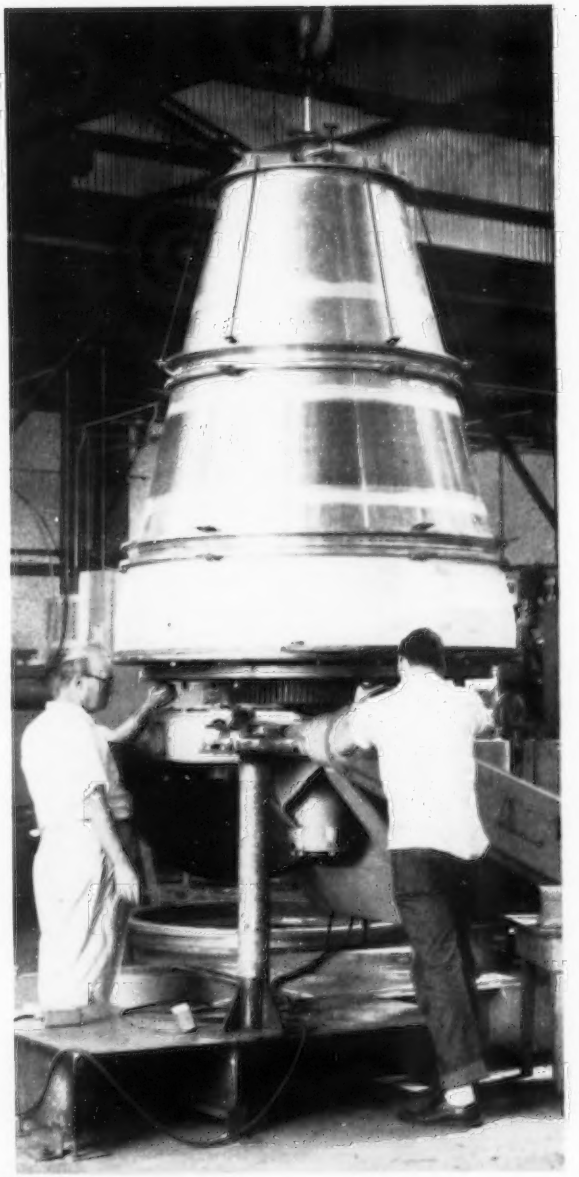
range: 1200 mi attained with nose cone reentry vehicle in August 1957
length: 69 ft (including Explorer)
diam, first stage: 5 ft 10 in.
thrust, first stage: 80,000 to 90,000 lb (est)
weight (total): 64,000 lb
powerplant, first stage: North American Rocketdyne
propellant, first stage: Hydyne—LOX
powerplant for second, third, and fourth stages: scaled down, solid-propellant Thiokol Sergeant rockets

hybrid Jupiter C

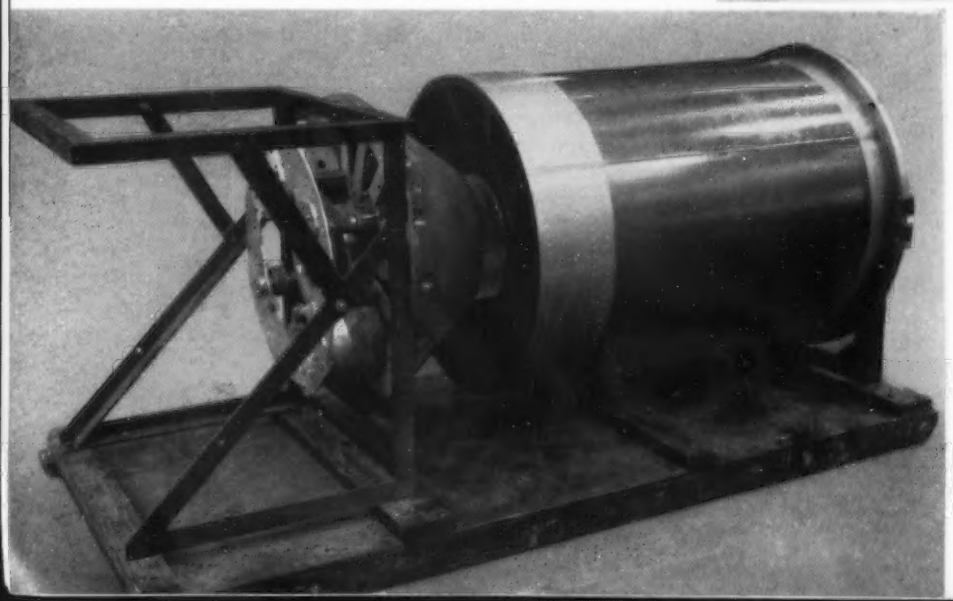
continued

stone Arsenal, Huntsville, Ala. The Redstone, presently the largest service missile of the U. S., is a direct descendent of the V-2. It has been produced and tested extensively enough to attain the high level of reliability required of weaponry for field use. It has also served as a test bed for a considerable portion of components which eventually constituted its more sophisticated offspring the Jupiter IRBM. The current version of this missile is powered by a liquid-propellant engine, developed by the Rocketdyne Division of North American Aviation, Inc., with a thrust of about 150,000 lb; nearly double that of the Redstone. In addition, while the Redstone is controlled by means of graphite vanes below the combustion chamber and additional external ones on its four fins, the Jupiter IRBM is controlled more accurately through its swiveling combustion chamber.

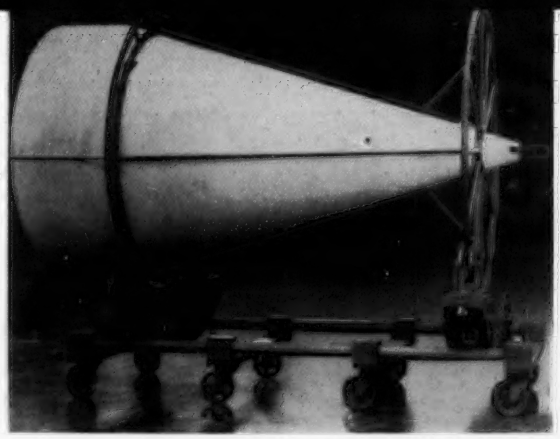
Jupiter-C was developed as a test vehicle in connection with the nose cone re-entry investigation which culminated in the successfully recovered cone introduced by President Eisenhower. Jupiter-C however, which lifted the Explorer, is more of an elongated Redstone with control vanes, than Jupiter IRBM; the elongation of body having been effected to accommodate additional fuel for a longer impulse. Also, "Hydyne" fuel, a member of the recent high-energy hydrazine family has increased the thrust of Jupiter-C to nearly 90,000 lb.



Nose cone of Jupiter-C, shown held upright could be tilted 90 deg for radial welding, was manufactured at Reynolds-Metals at Sheffield, Ala.



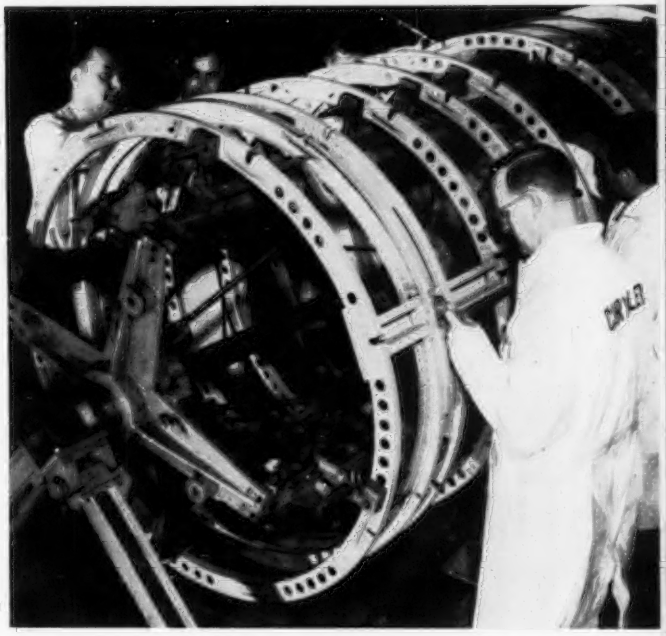
Spin launcher shown mounted on shipping pallet reveals spinning mechanism and spider bulkhead under pod.



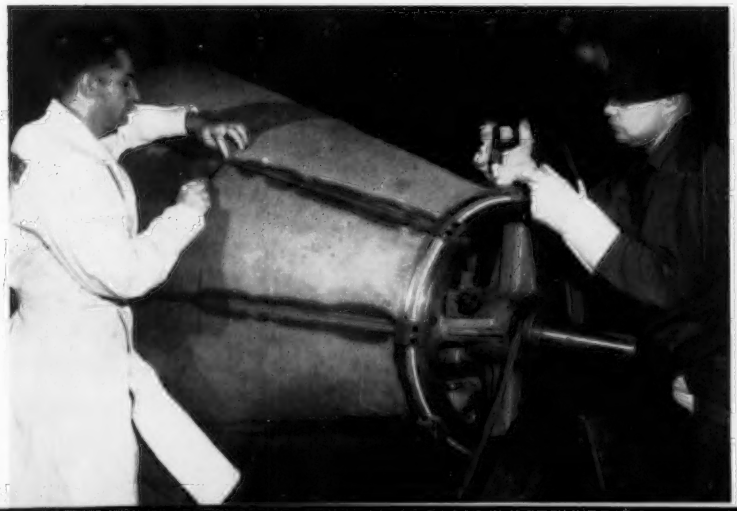
"Wagon wheel" dolly devised at Chrysler facilitates the conveyance, positioning, and installation of Redstone nose cone assembly.

Assembly of nose cone and guidance section housing is accomplished by bolting through the peripheral niches, which will be covered later.

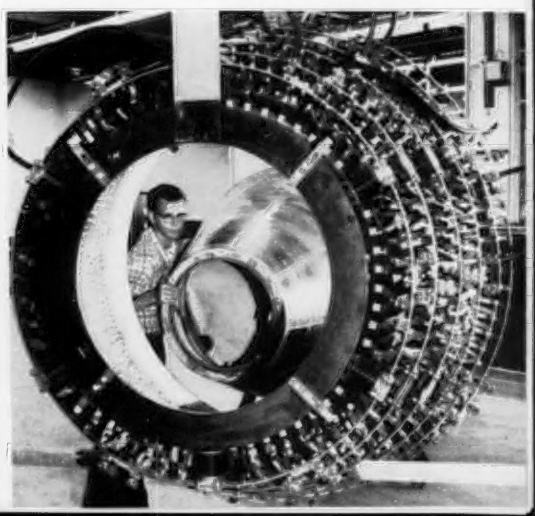
Horizontal rotating jig is utilized to position frames of Redstone forward section.



Nose cone section of Redstone missile is assembled by riveting radially to internal bulkheads, and inert-arc welding to longitudinal stiffeners.



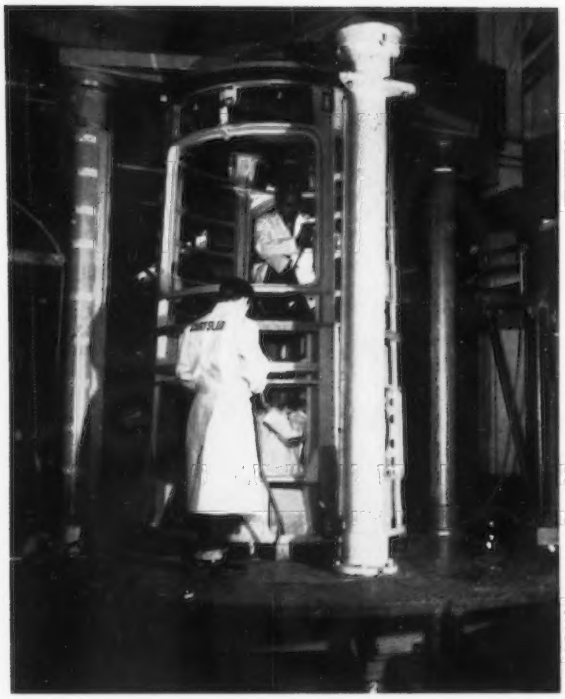
Quartz lamp oven developed by Chrysler duplicates re-entry temperature conditions to test the nose cone of the Redstone.



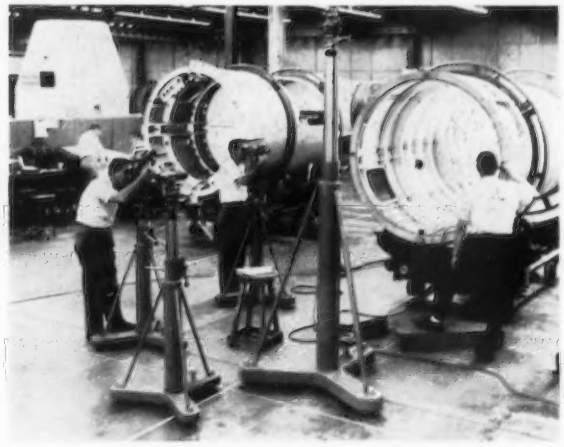
hybrid Jupiter C

continued

Immediately prior to the launching, a spinning motion of about 750 rpm was imparted to the cylindrical pod containing the second, third, and fourth stages, through a ground source of power to provide gyroscopic stabilization. This action commonly associated with bullets and shells, in addition to providing directional stability, in this case was particularly desirable to maintain symmetry of thrust in the event an unbalance occurred through the misfiring of elements in the second and third stages.



Massive vertical fixture is used to maintain forward frame assembly of Redstone rigid for riveting.

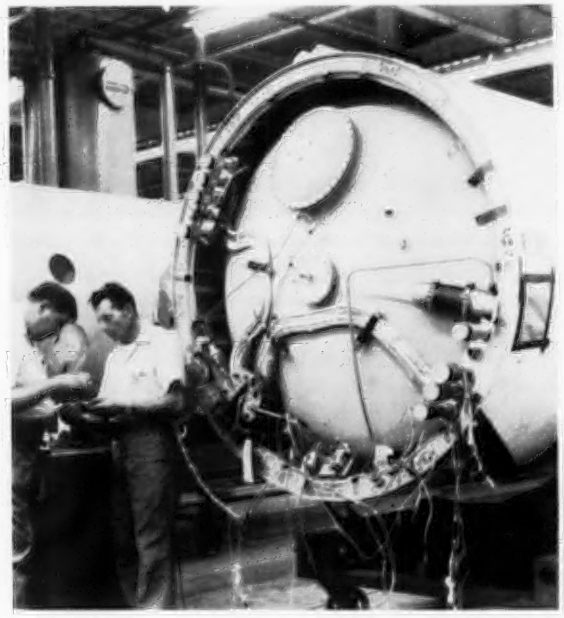


Optical checking of Redstone front section alignment.

Riveting of skins is done on horizontal fixture. Friction belt drive facilitates rotation of structure.

Internal view of Redstone front section. Inspection prior to the installation of guidance equipment

Final pressurization test checks components of fuel system to insure against failure during operation.



Front end of Redstone booster section being prepared to receive forward assembly of missile.

Redstone fin section manufactured at Reynolds reveals wedge-shaped bracket structure providing stiffness at jointure between skin and terminal frame.

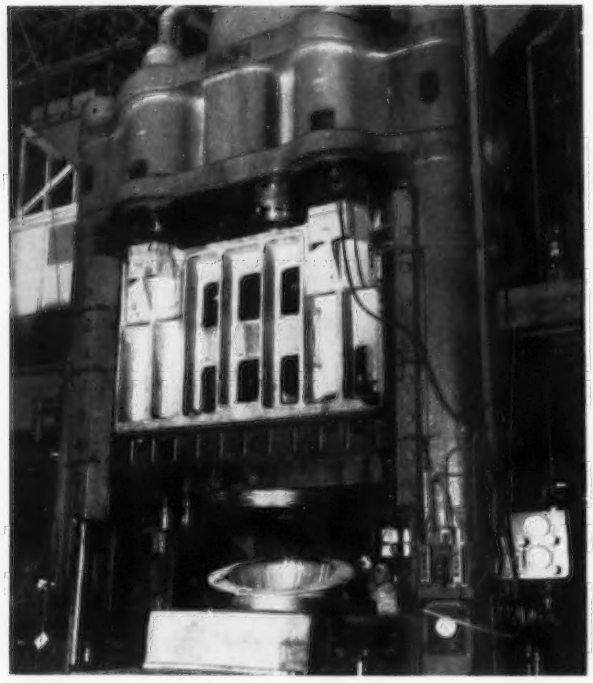
CREDITS

TO	FOR
Air Force Cambridge Research Center	Micrometeorite counter instrumentation
Army Ballistic Missile Agency	Project Development and Coordination
Ford Instrument Div., Sperry-Rand	Guidance System
Jet Propulsion Lab, Cal Tech	Transmitters, solid propellants, and Explorer assembly
Lodge and Shipley Co.	Explorer nose cone
Reynolds Metals Co.	Jupiter-C special nose section, spin-launcher pod, and fin section
Rocketdyne Div., North American	Liquid-propellant engine
Temple University, Philadelphia	Micrometeorite detector and high temperature research
Thiocol Chemical Corp.	Solid-propellant Sergeant rocket
University of Iowa	Cosmic-ray instrumentation

Bomarc tank production

material compatibility studies and stringent process control insure integrity of highly stressed parts.

by S. Peter Kaprielyan



1800-ton Southwark press drawing hemispherical ends for pressure tanks.

"Control" is the watchword at Kaiser Metal Products, Inc., Bristol, Pa., where their Fleetwings Division manufactures the pressure vessels for the Bomarc guided missile. These vessels are manufactured under subcontract to the Boeing Airplane Co. of Seattle, for the Air Force.

Working with stainless steels under critical specifications is not a new endeavor at Fleetwings. Their experience predates World War II when they pioneered in the fabrication of some of the first all-stainless aircraft. The manufacturing facilities of Fleetwings and their previous know-how were particularly adaptable to the production of the Bomarc tanks. In this instance, the precipitation hardening 17-7PH stainless alloy is used exclusively to obtain the optimum in weight-to-strength ratio.

Material Characteristics

It is a known fact that PH grades of stainless steels attain their maximum strength through a final aging treatment. This means that two factors, chemical composition and heat, must be accurately selected, matched, and controlled to produce the required physical properties. Hence, the requirements for stringent control begin with the selection of stock, and extend through the last operation which is the aging heat treatment. 17-7PH, as a member of the austenitic family of corrosion resistant steels, is characterized by the combination of a high coefficient of expansion and low heat conductivity. This necessitates measures to check distortion.

It is general knowledge that all welds tend to shrink within their heat area. This, coupled with the coefficient of permanent expansion for 17-7PH makes control obligatory also throughout welding. However, this does not imply that 17-7PH is an unstable material. On the contrary, it is stable; but its characteristics must be respected to achieve the optimum mechanical properties required for this application. It has the ductility needed for cold working, and lends itself readily to fabrication by rolling, deep-drawing, and machining.

Production Engineering Approach

The two major components manufactured by Fleetwings are the fuel and the oxidizer tank assemblies. In addition to being rocket fuel containers they also constitute sections of the fuselage of the missile; as such, they are required to carry a considerable amout of internal weight as well as external flight stresses. Close tolerances are

also required for tank exteriors since approximately 80 per cent of tank periphery is exposed to the airstream.

The planning of manufacturing operations, in a manner to anticipate and counteract the factors of weld shrinkage and expansion, has called for considerable forethought and experimentation. Since product specifications gave only the dimensions required of the finished product, Fleetwings' engineers had to establish preliminary component dimensions prior to welding and heat treatment then, with the assistance of metallurgists, welding, and tool engineers; test and adjust these as needed to produce the dimensions called out. This has been accomplished with considerable success. All assemblies now have detail drawings which are complete within themselves. All dimensions include compensation for both shrinkage and expansion as determined by tests.

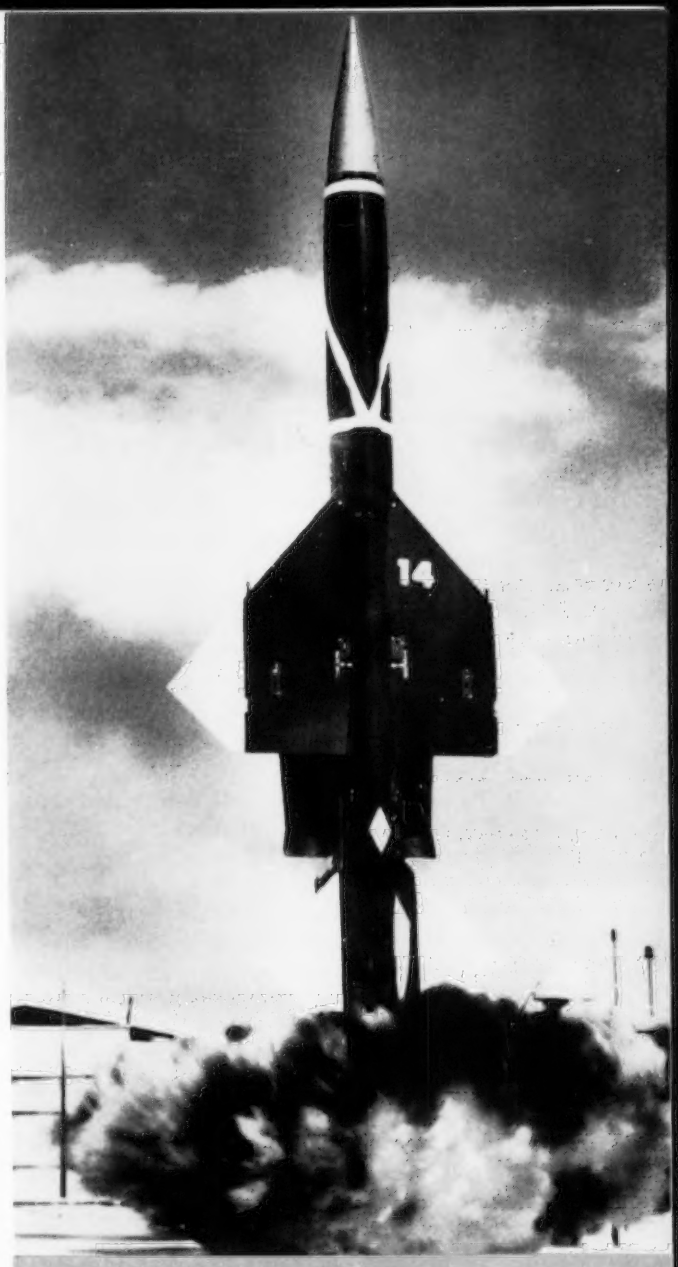
A complete set of sub-assembly and preheat-treat final assembly drawings have also been released, covering the sequence of operations as planned by the tool engineering department.

Tooling for Production

The stringent strength requirements for the pressure tanks have made assembly by fusion welding mandatory. To accomplish this on a production basis with minimal variations in operator technique, automatic equipment is utilized. Fleetwings' engineers designed and built the positioning and welding fixtures shown in adjacent illustrations. The automatic welding heads for inert-arc, used in this instance, are commercially available equipment.

But the accomplishment of automatic or semi-automatic operations with repetitive accuracy required the elimination of as many variables as possible. Here, the precision of fits between mating parts influenced to a great extent the quality of welds. It is also noteworthy that welding tools tolerances of ±0.003-in. are not unusual for these applications. Tools must be practical, accurate, and sturdy enough to withstand the shrinkage pressures during welding.

The general design of inert-arc welding back up tools incorporates a copper alloy faced plate in the case of longitudinal welding, or a copper faced expandable ring for circumferential work. A groove in the copper face allows space for the underbead of the weld, to promote penetration and fusion in the underface of the joint. The contour of this groove also lends its shape to the underbead and eliminates, to a great extent, unevenness or the occurrence of sharp edges and corners, thereby checking notch sensitivity. Considerable pressure is maintained during the welding oper-



The Air Force recently announced a $46 million program for the construction of four Bomarc sites equipped with storage, maintenance, and control facilities. These sites will become part of the U. S. Air Defense System extending along both coasts and the northern boundary. They will be located at McGuire A. F. Base, N. J.; Suffolk County A. F. Base, Long Island, N. Y.; Otis A. F. Base, Mass.; and Dow A. F. Base, Me.

Bomarc tank production

continued

ation to prevent material distortion and block off the air from the molten pool at the underbead, and thus prevent oxidation of the weld. The upper surface of the weld is protected from the air by a shield of inert gas such as helium or argon.

Material Compatibility Determination

Thus far, the engineering and tooling aspects of this project have been discussed with little emphasis on material properties.

The absence of the human pilot in missiles allows paring down the safety factor to a greater extent than in manned aircraft. However, rigid controls must be maintained to produce a weapon safe for storage and handling yet have reliability in operation.

To promote the requisite safety and reliability it is essential that all materials used within the pressure envelope of the vessel be compatible with one another. Compatible, by definition, means to coexist: to be different, yet to respond similarly to the same environment. Compatibility aspects encountered here are no less significant than those involved in a human marriage. This implies that the maximum efficiency of the pressure tanks can only be derived from the extreme uniformity of mechanical properties of the stock material, in the various tank components. This consideration is paramount, for the final heat treatment, which is the aging cycle, tends to magnify even the slightest variations in material to the extent of rendering it unsafe for operational loads.

To promote compatibility, each mill heat and gauge of stock and all welding wire received is tested chemically and mechanically to determine its response to heat treatment. It is also tested for its response to welding which will be covered in a later paragraph.

A piece from each heat and gauge of stock received is selected at random and machined into a standard metallurgical tensile specimen. A number of these specimens is heat treated to tank specifications at 1050°F, and the remainder at 1100°F. These specimens are then tested in the process laboratory for mechanical properties: ultimate tensile, yield, elongation and Rockwell hardness. Values from the two heat-treat lots plotted on a graph and a curve is established. By further plotting the specification limits, it is possible to extrapolate a range of temperatures at which the material may be heat treated. It therefore becomes evident that all heats and gauges of material, which are welded into one tank, must have mechanical qualities which tolerate a common aging temperature.

Without the above methods of control it is entirely conceivable that materials of unequal strength could become part of the same vessel and consequently could not carry their equal share of the operation loads. To prevent this, all stock is graded by its temperature range and is released for manufacturing only on a selected basis. The material release system although intricate, has proved economically feasible without excessive scrappage; most categories of materials are eventually matched with compatible mates.

Control of Welding Quality

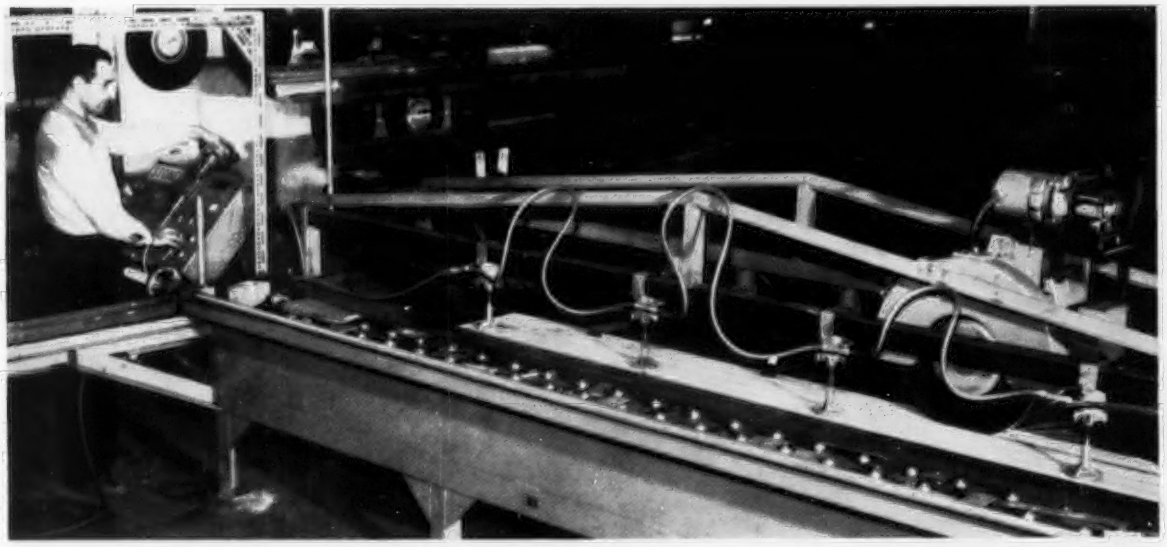
The development of correct welding criteria at Fleetwings is the responsibility of the materials process laboratory. In contrast to the desirable characteristics of the 17-7PH alloy, which make it suitable for welded pressure vessels, are its constituents of aluminum and delta-ferrite which tend to reduce weld ductility. Taking this into account, and using data from the material compatibility tests, the materials process laboratory compiles inert-arc welding parameter schedules for each heat and gauge, and each combination of heats and gauges for radial, longitudinal, and circumferential welding. These schedules provide the production shop with the optimum combinations of welding speed, current, arc voltage, wire feed, nozzle type, joint design, etc.

The production welder uses these predetermined schedules for his initial welding machine settings and adheres to them strictly. At the completion of his weld he fills out a check list upon which he notes the schedule number and weld joint identification number. He also makes comments regarding any peculiarities he noticed during the cycle and the adjustments he was required to make. A welding engineer is available at all times for consultation or advice. These check lists provide information for research and tracing defects to their sources.

To insure soundness of seams throughout the tank assembly, every inch of weld is rigidly inspected: visually for contour conformance, with dye-penetrant for surface defects, and by x-ray for internal defects. Permanent records are kept of all defects in order to continually check back and effect positive corrective action.

Removal of Defects

Where isolated weld imperfections occur,



Abrasive cutting machine provides sheet stock with clean square edges for good welded joints.

the localized defect is removed by meticulous grinding as in dentistry. The cavity produced is re-welded and completely re-inspected. In a typical week, out of thousands of linear inches of weld, a small percentage may need rework by this method.

Both fuel and oxidizer tanks are similar in general construction, and the same controlled manufacturing sequence is used; however, the fuel tank is actually a composite assembly of a pressure tank and fuel tank, which merits some elaboration.

The composite fuel tank assembly has a hemispherical and a conical end. While the conical end is a direct part of the fuel tank, the hemispherical end belongs to the pressure tank.

Fleetwings manufactures and pressure-tests each of these tanks separately. The fuel compartment of the above assembly does not become a closed vessel until the final integration of the pressure tank. A dummy hemispherical head is welded to the open end of the fuel compartment as a closure. This closure serves the following purposes:

1. It stabilizes an otherwise open end cylinder during manufacture.

2. It acts as a closure to confine argon gas used for purging, during heat treatment.

3. It serves as a pressure head during testing.

After pressure testing, the dummy head is machined off, including the weld; and the skirted pressure tank is joined by welding to the fuel compartment. To prove the effectiveness of the last weld a final pressure test is undertaken. Each pressure test is followed by fluorescent dye penetrant and x-ray inspection of all fittings, threads, and welds.

The pressure tank is composed of two drawn hemispherical ends of 0.410-in. material and a short cylindrical 0.650 in. mid-section. Later, skirts are added to provide a continous cylindrical configuration. The welding of the three heavy main sections of the pressure tank is accomplished in seven consecutive passes for each joint, with stringent inspection and cleaning after each. As stated before, the quality of a welded joint is also determined by the accuracy of mating. To this end, the tolerance is kept within ± 0.005 in.

Heat Treatment Procedure

The control requirements for this phase are no less stringent than those for the preceding ones. Before heat treatment, a series of numbered test coupons are wired upon the tanks to undergo the effects of heat treatment of the tank itself. Later, by testing these coupons it becomes possible to detect regional variations of the tank material. To prevent scaling, all threaded fittings are coated lightly with silicone oil, and plugged.

Annealing

The fuel tank is purged with argon for 60 min, and the inert internal atmosphere is retained

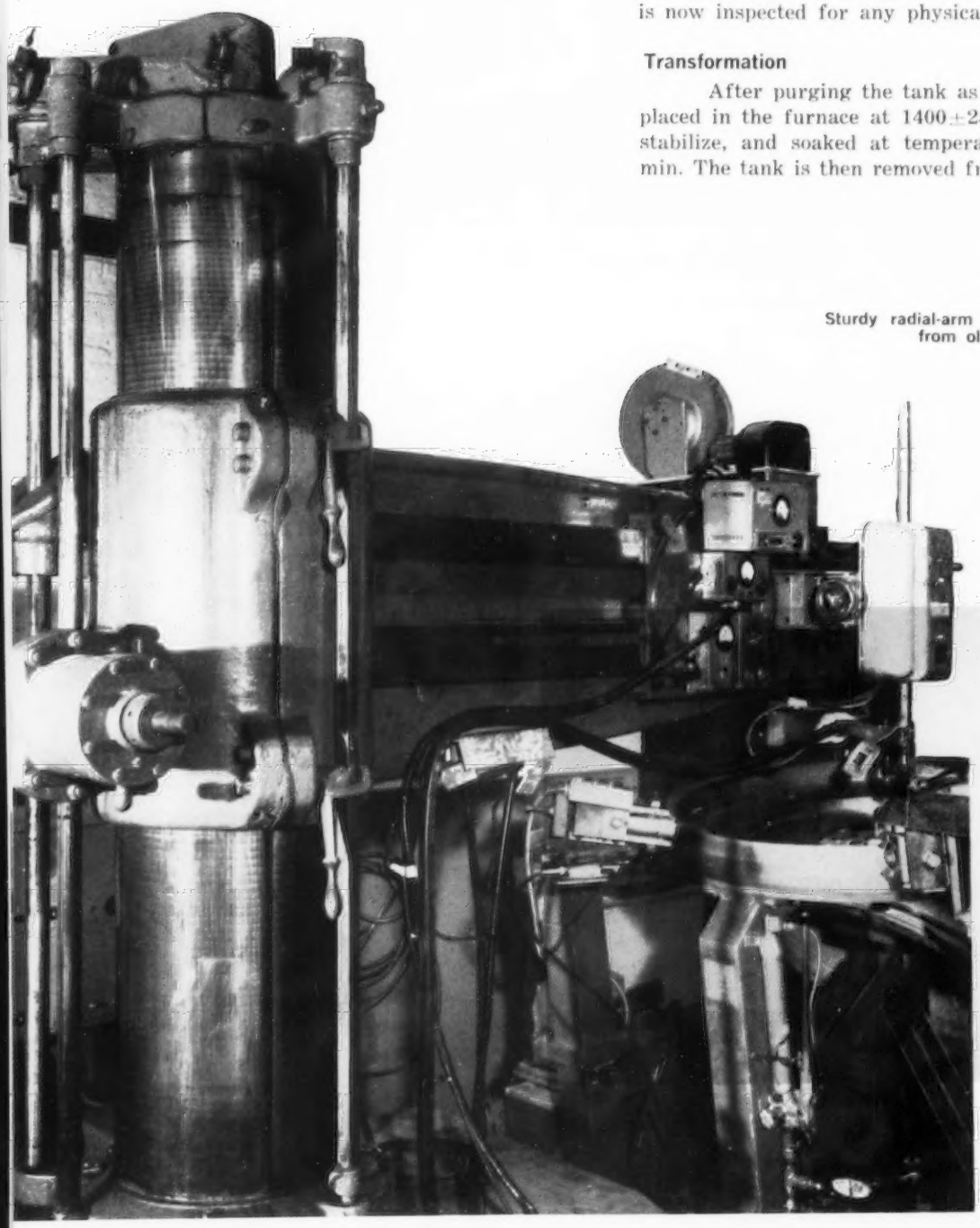
Bomarc tank production

continued

throughout the heat-treat sequence. The tank is placed in the furnace at 1400±25°F and time allowed for temperature recovery. After one hour ± 5 min at temperature, it is raised to 1825±25°F and retained there for 20 (tolerance+5,-0) min. Upon removal of the tank an air blast is applied with a uniform circular motion to all heavy fittings and heavy sections, until the entire tank is black. Uniform cooling is continued at room temperature until 200°F or lower is reached. The tank is now inspected for any physical irregularities.

Transformation

After purging the tank as above, it is replaced in the furnace at 1400±25°F, allowed to stabilize, and soaked at temperature for 90±5 min. The tank is then removed from the furnace



Sturdy radial-arm welder improvised from old radial drill-press.

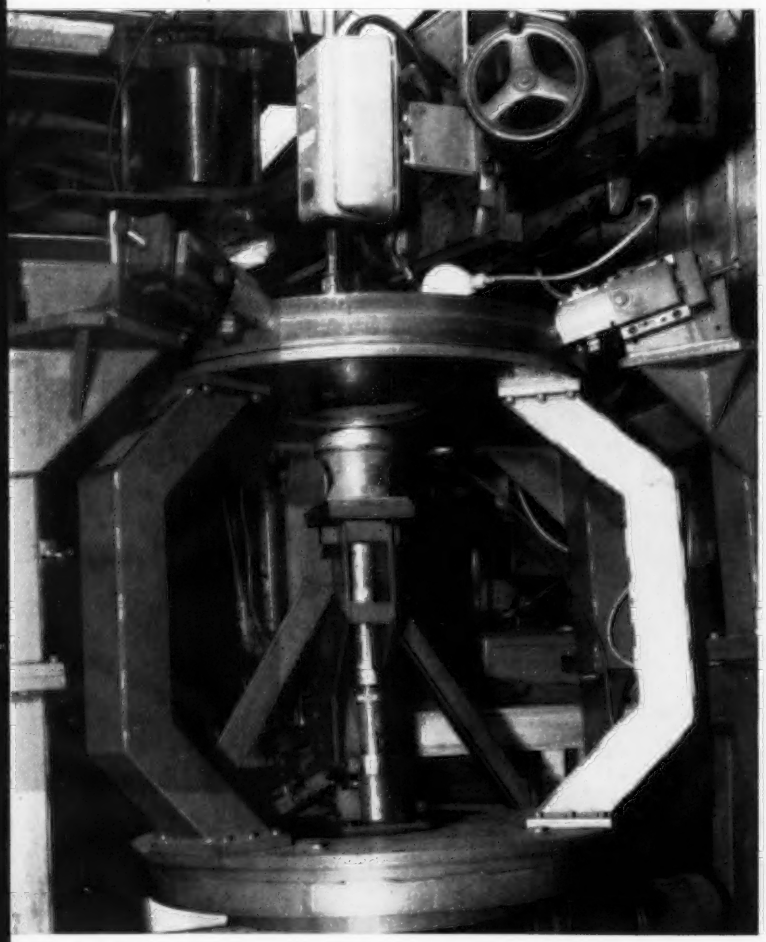
and cooled to below 60°F within one hour. This is accomplished first by air blast, as before, for 35 min (max.) or until 200°F is reached; followed by a quick (5 min) replacement of the heat treat plugs with sealing plugs and further uniform cooling in a water spray with the water temperature at 60°F or lower for 60 min.

Aging

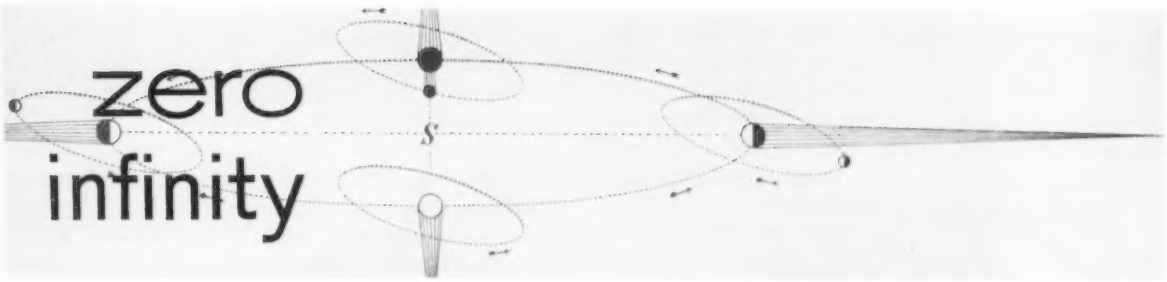
After the tank is completely dry internally, the heat treat plugs are replaced and a thermocouple is attached at each end of the tank, between the tank and a test coupon. Both thermocouples are now connected to a temperature recorder to provide a complete time-temperature record of the aging cycle. The data obtained from the initial stock compatibility studies now determine the aging temperature range appropriate to the tank at hand. Accordingly, the tank is placed in the furnace and the applicable temperature range is established and maintained within ±5°F. After the thermocouples have reached the prescribed temperature, soaking takes place for 90±3 min. Thereupon, the tank is removed from furnace and rapidly air cooled to room temperature. The interior surfaces are immediately coated with a rust inhibiting solution composed of 1 part Immunol #1392 to 100 parts of water.

When the remaining applicable assembly procedures are complete, the tanks are pressure tested, protected, and shipped to Boeing accompanied by complete inspection records.

If in the foregoing account of Kaiser Metal Products' contribution to our national defense, excessive stress has been placed upon stringent controls, this is because the dictates for reliability in modern weapons systems demand no less.



Special positioning fixture used in conjunction with radial-arm welder facilitates jointures in spherical and conical shapes.

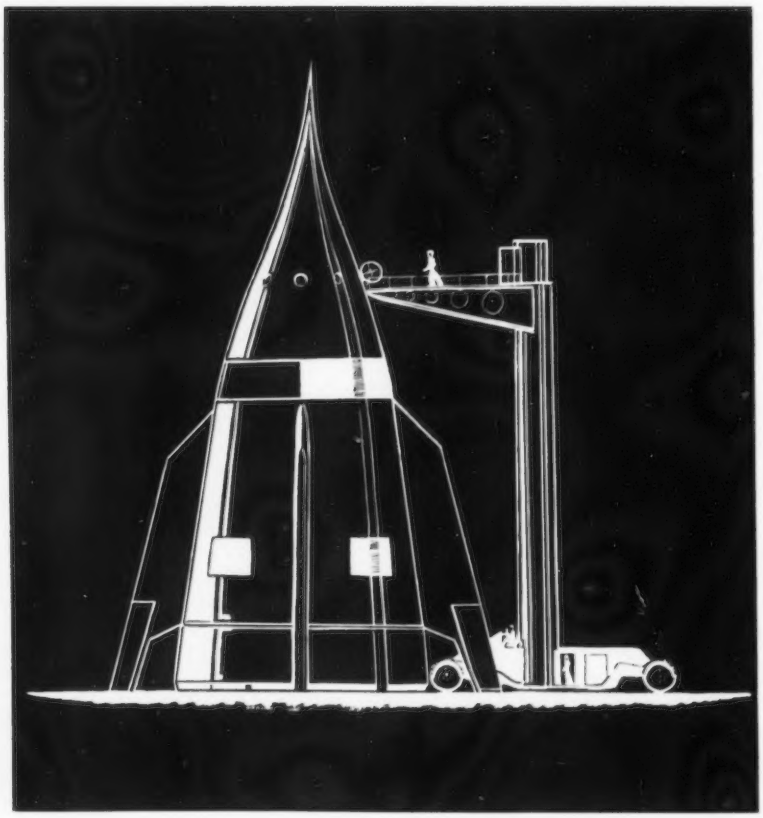


This department is created to encourage thinking in new dimensions: thinking that is free of the often constraining influence of immediate difficulties. Technological progress is to a great extent based on departures from the conventional or the status quo. That which is considered illogical or impossible to accomplish, has and always will be so only within the limited compass of accumulated knowledge up to a particular date. Speculative thinking is man's most precious asset. It is hoped that this department will provide an outlet for such thinking and will serve to stimulate further ideas. The implications of the symbolism for this department head are that: while the immediate worth of a concept may range from nil to infinity, its true value will only be determined in the ultimate.

closed propulsion system

are they possible for space flight?

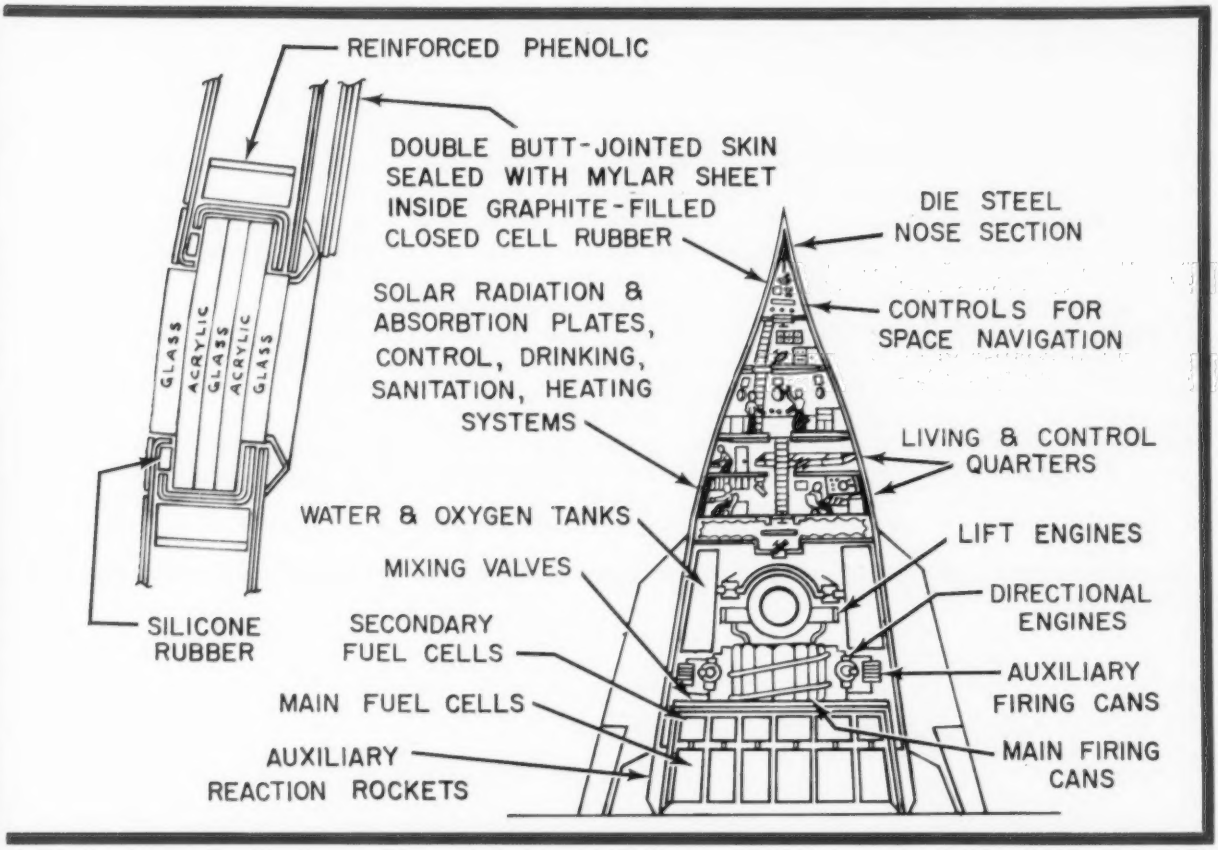
by Philip S. Egan, Industrial Designer



At the present time, there is a general assumption that the space vehicle of the future will be a rocket. It is envisioned as an object which will be poised like a bullet and at some appointed second have tons of corrosive and highly volatile fuels combine ferociously to release the thrust that will propel the rocket out of the earth's atmosphere.

Slowly at first, the rocket will rise and then it will hurtle at tremendous acceleration toward its destination.

A second assumption seems to be that one vessel will not have enough fuel to make it to the moon, Mars, or . . . The first leg of the journey will be to a satellite space station. A second space ship will be transported to and assembled at the station in bits and pieces. Eventually an odd-shaped vehicle will accelerate out of the lesser gravity and wend its way to its destination.



Unresolved Problems

There are a number of unresolved problems in this scheme. For some reason, we seem to assume that these problems are the natural problems of space flight.

One of these is weightlessness. Because of the rapid expenditure of fuel in bringing the ship to speed early in flight, it will have to coast for vast distances in space and reserve some small portion of fuel for detail navigation.

There are good reasons why we should not toy with the idea that weightlessness is a phenomena we must learn to tolerate in space flight. First, it is an inconvenience of the first order to the crew. Second, the research alone necessary to explore its effects and design around it would run into billions of dollars.

Since the first space ships will be flying laboratories, it is not illogical to assume they will be instrumented with the same variety of instruments as an earth laboratory, with men free to observe and operate them. A "gravity producing" vehicle would be a far sounder approach to the laboratory space ship.

A second problem few futuristic envisionments of space travel seem to care much about is piercing of the rocket to shreds by meteors, big or small. Meteor bombardment is viewed as a calculated risk.

The present stage of planning for space travel parallels very closely the stage of development of aviation that lead to trans-oceanic travel. For many years, scientific and popular-scientific journals speculated about platforms built on huge floats interspersed across the Atlantic to receive planes on legs of the journey across the ocean. The popular assumption then was that sufficient fuel for a nonstop journey could not be lifted off the ground at departure, and that easy stages were the means of traversing the ocean.

It is undesirable to carry similes too far, but it may not be a stretch of imagination to compare the ignoring of meteor hazard in space travel to the naiveté about icing hazard that accompanied speculations regarding the design of trans-oceanic aircraft.

"Gravity" by Acceleration and Deceleration

A space vehicle of approximately the configuration illustrated is a new concept, free from many of the shortcomings discussed. It will be a nonstop ship, with ample fuel aboard for an entire round-trip space journey. It will not coast in space and bring about weightlessness to itself and its crew, nor will it be one to subject any person or

closed propulsion systems

continued

instrument aboard to any undue acceleration forces at departure. It will develop, by constant acceleration for one-half the journey, and constant deceleration for the other half, gravitational effect equal to a designed two feet per second — or four, or eight, etc.—rate according to convenience levels and the elapsed time for the trip.

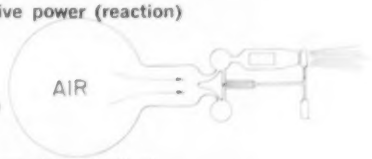
To achieve this built-in gravity factor, it will be powered by a levitation engine, mechanical and/or electronic in nature. Fuel burned, if not nuclear, will be combined in burning cans and fed into a semi-closed circuit of impulse and reaction. The free piston engine, arranged to generate centrifugal forces in a directional resultant, is an example of the mechanical principle involved. Electronic or gaseous emission might augment burning and reaction or, later, do the job itself. The total energy consumed will be husbanded for the trip, and not burned in a fury of moments in the need of accelerating the vessel to twelve miles per second velocity to escape gravity in a subsequent "coast" out into space. Instead, the vessel will work out of gravity with ever-

The normal engine provides tractive force by generating a reaction against the air

or against the ground.

The jet engine generates its own reaction by combining combustibles.

Theoretically the jet should provide motive power (reaction) for space travel if an infinite air supply chamber could be provided.



Since this infinite air supply is not possible the nonair-breathing rocket is a seeming answer for a space flight propulsion system. It provides thrust, far in excess of what is needed, but it provides it all at once. Once its power is shut down or expended the space vehicle would coast in space causing weightlessness. There must be another way. Leave us get very basic in an effort to find a clue. The sailboat with its own fan will not move because the reactions are as in Newton's Third Law.

Disconnecting the reactions will however produce motion in the sailboat.

A man seated in a sailboat cannot blow on the sail to make the boat go.

But if he were to jump up the boat would go because the reactions become disconnected.

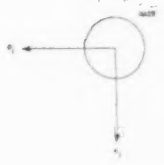
We still must contend with the R_2 imparted to the man, for when he lands back in the boat it will nullify R_1.
Suppose the R_2 that the man imparted to himself were largely absorbed by inertia, so he would be virtually free of R_2 by the time he landed back in the boat.
The boat would continue to go as he provided an R_1.
Let us examine the flaws in this oversimplification and take them along with us knowing they exist. First, the man as a source of energy has to be accelerated too, if we are considering a space vehicle.

accelerating force, gaining velocity by two factors. One, the constantly lessening gravity, the other, the inertia loss due to fuel consumption, both acting to augment the rate of acceleration generated by a constant force of levitation. Laboratory studies, instrument observation, computing, eating, drinking, sanitary functions (even the flow of water in a plumbing system) will all be only moderately affected compared to earth.

At the halfway point in its trip, it will turn around by lateral reaction lift engines, and decelerate to zero calculated velocity at the destination. It will have fuel left to repeat the performance for the return trip, accelerating against the lesser gravity of the Moon or Mars in early days of exploration. Neither the amount of fuel carried, or the navigational accuracy required, will be as critical as that so often envisioned today.

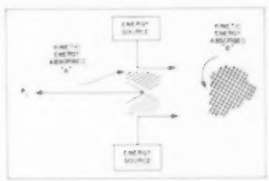
When man eventually achieves some dream that he has been working on for a long time, he usually does it infinitely better than any predictions dared hope.

So, let us rotate the energy source 90 deg to place R_2, on an energy time basis, at right angles to R_1 and simply treat the energy source mass as part of the total vehicle weight.
In this manner:

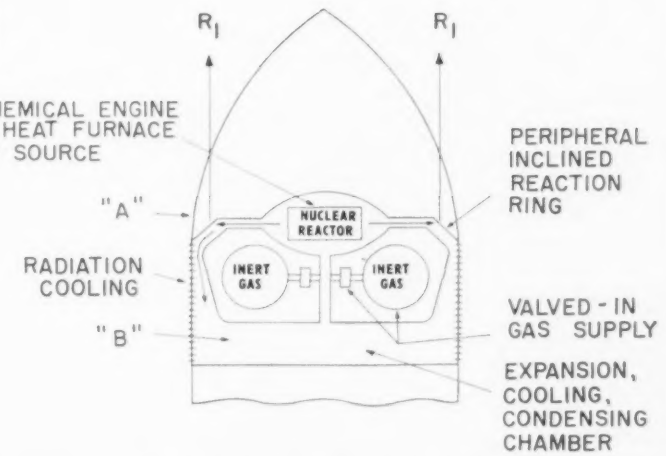


But, even if this were possible we would get some rotation.

So let us balance R_2 with an equal and opposite reaction, in this way we get a vector R_1 that will produce motion. If we now contain all of this and absorb the kinetic energy by doing work, at "A," and by another means at "B" (this can be by cooling expansion, magnetically, mechanically, electrically, or other means) we have a means of, conserving fuel and conserving (almost totally) the kinetic energy vehicle for constant use and re-use. This is a means of providing self-contained thrust on a scale designed for space flight.



We have illustrated here the cross section of a typical closed propulsion system power plant and vehicle. Another cross-sectional view appears on the previous page. It can be seen that the closed-circuit circulation of a gas, or a liquid, heated, forced against "A" and dissipated finally at "B," provides the propulsive action as illustrated above. Essentially what is provided is a self contained thrust system — or "levitation" on a scale for space travel.



DESIGN

Tools for Bonding.

H. T. DUFFY. *Acft. Prod.*, (December 1957), 4 pp.
Equipment and methods used in contouring the dihedral break area of wing skins.

Elevator Locking Bars Withstand Increased Nike Thrust.

Design News, (January 6, 1958), 2 pp.
Four inverted "L" shaped steel bars automatically engage a 25,000 lb elevator platform holding Nike Hercules missile and its launcher enabling the platform to withstand rocket firing thrusts greater than its own weight.

MATERIALS

At 3000°F . . . CRC + Chrome-Case Outlasts Stainless Steel 5 to 1.

W. M. STOCKER, JR. *Amer. Mach.*, (November 18, 1957), 2 pp.
Chromized CRS heat shield resists temperatures of 130-million-candlepower airborne searchlight developed by Arma.

North American Research on Machining Titanium Alloys.

KENNETH LOO. *Mach.*, (October 1957), 5 pp.
Discussion of results obtained from an experimental program established to determine design and producibility criteria.

Glass Reinforcement for Structural Plastics.

R. G. ADAMS and RALPH SONNEBORN. *SPE Journal*, (December 1957), 3 pp.
Background information on all available glass reinforcing materials, how they are fabricated and processed, and what to expect from each.

PRODUCTION

Integral Components.

H. YOUNG. *Acft. Prod.*, (December 1957), 7 pp.
Machine-tool equipment and methods adopted by Avro Aircraft, Ltd., of Canada for the manufacture of large integrally-stiffened aircraft components.

Three-Dimensional Model Simplifies Compound-Angle Setups.

O. SKILB. *Mach.*, (January 1958), 4 pp.
Visual aid helps position work-pieces for machining when proper setup is not readily apparent from working drawings.

First Peek at Chrysler's Redstone.

Steel, (October 21, 1957), 2 pp.
Pictures show various stages of production.

Motor Makers Discuss Aircraft Construction.

J. L. MCCLOUD. *Metal Progress*, (December 1957), 5 pp.
New problems are introduced by such production methods as electrolytic grinding and vacuum metalizing. The methods of machining, bonding, and plating new high strength sheet steels are also discussed.

BOOKS RECEIVED

Manufacturing Methods and Process.

A. C. Ansley. Chilton, 1957. 561 pp. $12.50.
This book is designed to give the executive, the purchasing agent, or the design engineer a broad, general background on the latest developments in manufacturing methods and processes. It can serve as text and reference book for technical, vocational, and college courses. Describing briefly the methods and equipment used in each of the processes and profusely illustrated with over 450 illustrations, the book placed its principal emphasis on the type of parts made by each process, brief applications, and cost.

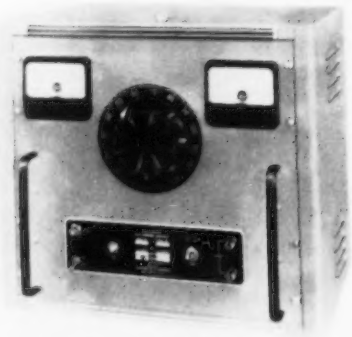
REVIEWED IN THIS ISSUE

Periodicals and Papers

Acft. Prod. Aircraft Production (British)
Amer. Mach. American Machinist
Design News Design News
Mach. Machinery
Metal Progress Metal Progress
SPE Journal Society of Plastics Engineers Journal
Steel Steel Penton Publishing Co.

Books Received

Manufacturing Methods and Processes Chilton



POWER SUPPLY ADJUSTS FROM ZERO TO 110V DC

A medium-voltage germanium rectifier power supply, Model RD40B, has a continuously adjustable output from zero to 110 v dc with a maximum load current rating of 20 amp. Ripple does not exceed one per cent of the average dc output throughout the range of the equipment. Regulation is five to six per cent from 1/10 load to full load at 110 v output.

The equipment is housed in a ventilated rack type cabinet 22 x 19 x 15 in. The unit is also available for mounting in a standard 19 in. wide rack and in this form occupies only 17½ in. of panel height.

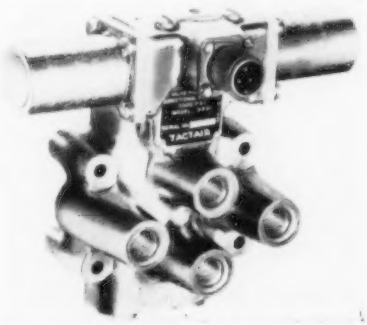
Opad Electric Co.

Circle 132 on postcard for more data

SELECTOR VALVE MADE FOR ROCKET RELEASE SYSTEM

A four-way, solenoid-operated, pneumatic selector valve, Tactair Model 9801, has been developed for use in a rocket release system. This valve is applicable where low leakage, small size, light weight, and a ½ amp current drain can be utilized. It is particularly useful where a quick activation or response is required.

To meet the requirements of the rocket release application,



the Tactair 9801 had to have: (1) an uncommonly wide pressure range of 500 to 3000 psi at altitudes from sea level to 70,000 ft, (2) extremely high flow capacity of 0.2 Qu for its light weight and small size, (3) a low external leakage of 3cc/hr max, and (4) a rapid operation time of 0.05 sec max to energize.

This valve has a forged aluminum alloy housing. It measures only 2¼ in. thick, by 4¾ in. high, by 5⅜ in. across the solenoids. It weighs less than 1.9 lb.

Aircraft Products Co.

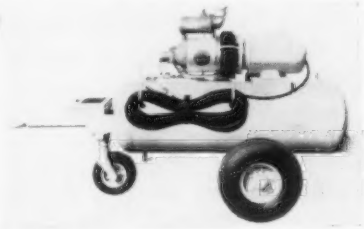
Circle 146 on postcard for more data

PORTABLE COMPRESSORS DELIVERS 16 CFM

An electric motor-driven portable compressor, capable of delivering 16 cfm at 200 psi, Model MB-2, is mounted on two fixed wheels and a retractable third wheel.

Compressor is an oil-cooled Hydrovane sliding-vane rotary unit. It is located atop the air receiver and connected directly to an explosion-proof electric motor.

It is 102 in. long, 44 in. wide, and 54 in. high. It weighs 800 lb. Designed for constant



operation at 200 psi, it can be run intermittently at 250 psi.

Originally built for aircraft industry use, the compressor complies fully with specifications MIL-C-8499 and MIL-C-26805.

Davey Compressor Co.

Circle 133 on postcard for more data

PERFECT THREADS PRODUCED WITHOUT EXPERIENCE

Designed as a compact, lightweight tapping attachment. Tapmatic "100" weighs only 10 ounces, has a maximum diam-

eter of 1⅝ in., and a maximum length of 3½ in. The rated capacity for tapping in steel is from No. 00 to No. 6.

The product features a lifetime positive torque control clutch, free axial floating action, and instantaneous planetary-ball reversing mechanism.

The human or mechanical "lead error" obtained with conventional attachments is eliminated by the free floating action of this unit. The dimensions and forms of the thread produced are solely dependent on the tap itself; a perfect tap will always produce a perfect thread even with inexperienced operators.

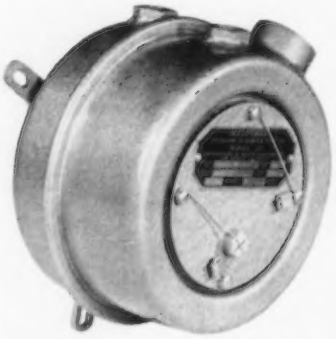
Tapmatic Corp.

Circle 257 on postcard for more data

SENSITIVE SWITCH USED FOR LOW PRESSURE WARNING

An extremely sensitive low-pressure differential all-aluminum switch is designated Model 217.

The reference pressure may be air or inert gas, and the



variable pressure may be liquid or gas. The fixed actuation valves range from 1.25 to 12 in. of water and the differential pressure settings from 1 to 22 in. of water, or .1 to 5 in. hg. It weighs on 1¼ lb, with a diameter of 6⅜ in. and a depth of 3¾ in. The switch is provided with an external adjustment.

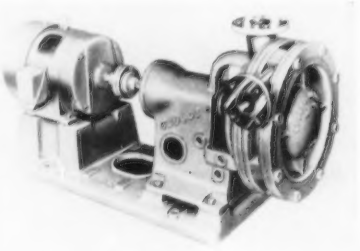
An example of its use is an airplane cabin low pressure warning device which will warn the pilot when the cabin pressure becomes too low.

Meletron Corp.

Circle 258 on postcard for more data

GLASSED-METAL PUMP SOLVES CORROSION PROBLEMS

The glassed-metal centrifugal pump solves a difficult problem for processing industries which handle corrosives, and which are faced with high pump costs, maintenance, and replacement. All inner surfaces of the pump are glassed so that the pumpage never comes into contact with metal. The pump design cuts down changeover time and eliminates the need for



stocking different pumps and pump parts to handle specific corrosion-producing products.

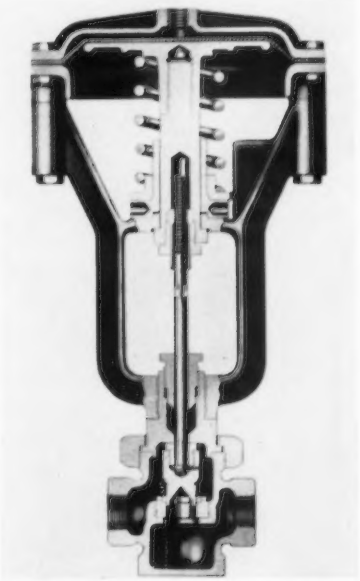
Goulds Pumps, Inc.

Circle 259 on postcard for more data

CONTROL VALVES ARE DIAPHRAGM OPERATED

A complete line of diaphragm-operated valves, designed for instrument-actuated control of temperature, pressure, or flow; is being produced.

Featuring exclusive V-port design, said to afford extremely precise modulation of flow because of its tapered variable port area, these valves are



offered in both direct and reverse acting types. Intended for steam, air, liquid, or gas service up to 250 psi, the valves are available in sizes ranging from

1/16 through 2 in. NPT (direct acting) and ⅛ through 2 in. NPT (reverse acting). Instrument air supply pressure requirements are from 2½ to 12 psi for the direct acting types, and 4 to 13 psi for reverse acting valves. Spring tension is adjustable.

Sinclair-Collins Valve Co.

Circle 260 on postcard for more data

AIR-PARTICLE RAY ACTIVITY

Simultaneous measurement of both alpha and beta-gamma activity of airborne particulates as they are collected is now possible for the first time with one instrument, through use of an entirely new air monitor.

Known as Model AM-33, the new unit combines in one integrated unit a detector, amplifier, discriminator, anti-coincident circuit, counting ratemeter, high and low voltage

power supply, alarm system, and continuous recording unit. The basic detector is a gas flow proportional counter which employs a thin mylar window.

Dimensions of the mobile style are 7-ft high x 24-in. wide x 25-in. deep. Weight is approximately 600 lb.

Nuclear Measurements Corp.

Circle 261 on postcard for more data

STEEL BLIND RIVET IS STRONG, YET LOW IN COST

A blind rivet fabricated of steel for high-strength, low cost fastening is a patented design that features a broad grip range. Widespread gripping leaves, formed from the split sleeve when the fastener is installed, make hole size a non-

critical assembly design consideration. Its trade name is "Daisy."

It is especially well suited to all types of light sheet metal applications. It is installed with standard pneumatic tooling. A swaged positive mechanical lock insures pin retention; the pin cannot rattle out or back out, even under conditions of high vibration.

The fastener is available in two lengths to satisfy a variety of application requirements. Each size has a 7/16-in. diam washer-type collar. One size has a ⅝-in. split-sleeve length and a 0.032 to 0.250-in. grip range; the other has a ⅞-in. split-sleeve length and a 0.032 to 0.375-in. grip range.

Huck Manufacturing Co.

Circle 262 on postcard for more data

MINIATURE SCREWS ARE INDEFINITELY RE-USABLE

Newest contribution to improved assembly methods for electronic parts is the introduction of miniature Hi-Torque screws.

Available in sizes as low as No. 2-56, the screw features

the unique Hi-Torque recess which gives positive gripping to the driver and prevents slipping damages to adjacent electronic components during assembly. The advanced design also gives indefinite re-usability, a highly important quality to electronic component manufacturers where frequent assembly and disassembly is a requirement.

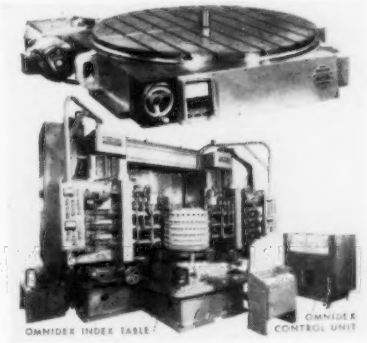
All screws are available in ferrous and non-magnetic metals for special electronic devices.

Voi-Shan, Pheoll Manufacturing Co.

Circle 263 on postcard for more data

INDEX TABLE IS ACCURATE TO ONE SECOND OF ARC

A 42-in. Omnidex table, electronically controlled by conventional tape or card, can be used with any standard or non-



standard machine tool of sufficient capacity. Used independently, it serves as a precision inspection machine. Both horizontal and vertical models are available.

Continued on next page

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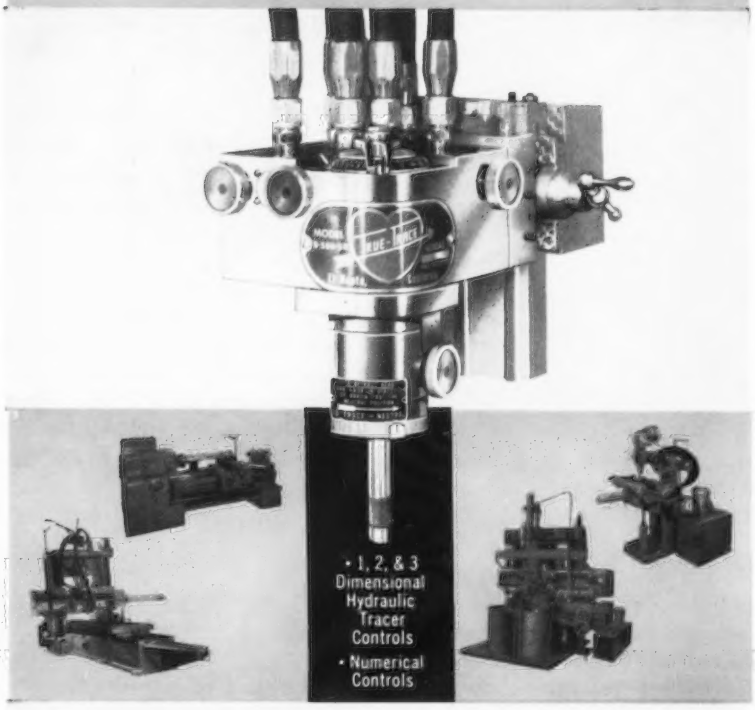

Outmoded, manually-operated machines cost money, reduce production capacity and waste skilled labor. Modernize your existing machines with **True-Trace** machine tool controls—increase your ability to produce high quality parts economically.

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Dealers in Principal Cities

Continued from page 61

The table surpasses current demanding standards of accuracy and efficiency by positioning to one-second of arc automatically. A built-in electronic vernier assures permanent accuracy, since no screws, gears, or counters are used to affect the measuring system, and no physical contact of gaging elements exists.

Superior Machine and Engineering Co.

Circle 264 on postcard for more data

JUNIOR TORQUE LIMITER HAS SIMPLE ADJUSTMENT

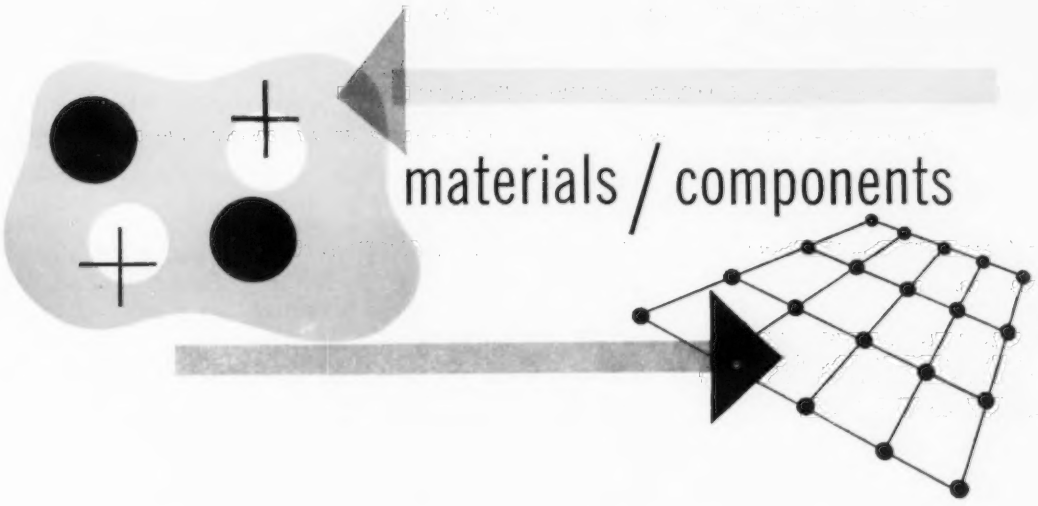
Adaptable to most powered screwdrivers for accurately torquing screws and bolts where the required torque range is between 2 and 25 in./lb. The snap-lock bit holder can use any standard ¼-in. hex bit.

The Junior Torque Limiter is designed for electrical and electronic component assemblies, or wherever small and fragile fasteners are used, and

where there is a danger of stripping threads or otherwise damaging fasteners. The Junior Limiter couples the advantages of power-tool speed with extreme accuracy. The tool can be set to the desired torque by a simple adjustment, which will hold indefinitely within tolerances of the best hand torque tools. Weight is 6 oz; length 4½ in.

Livermont Inc.

Circle 265 on postcard for more data

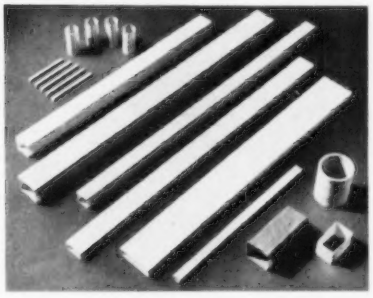


High Temperature Tubes Can Be Laminated

Rectangular and round high-temperature core tubes or coil forms without flanges are available as laminated silicone, epoxy, and polyester glass cloth.

Tubes ranging from 20-in. I.D. x 144-in. length x 3/8-in. wall thickness to 1/4-in. I.D. x 0.004 in. wall thickness are available.

Tubes can be cut to most



specified lengths or fabricated with holes, grooves, or slots. Maximum length is 72 in.

Silicone Insulation, Inc.

Circle 185 on postcard for more data

New Relay Operates at High Ambient Temperature

A miniature relay, which fulfills the Class C, Type II, Grade 3 requirements of Specification MIL-R-25018, MS-24114-9 has, under test, demonstrated

the following characteristics: Operates in an ambient temperature of 200°C, withstands in excess of 55G shock for 11 milliseconds, withstands 25G vibration up to 2000 cps, and a contact bounce of less than 250 microseconds.

The relay has a 4-pole, double-throw (4PDT) contact structure. A gold alloy is used for contact material for both low level and high level loads.

The relay is insulated with a ceramic material to withstand severe thermal shock.

Union Switch and Signal Co.

Circle 184 on postcard for more data

Elastomer Shows Promise As High Temp Lube Seal

Viton A, a heat resistant elastomer, shows promise for use as "O" ring and liner material in fuel lubricating and hydraulic systems.

Viton A has good resistance to compression set. It is virtually unaffected by standard fuels and oil and shows above average ozone resistance.

The elastomer will heat-age continuously at temperatures near 400°F. At 450°F parts remain serviceable for about 1000 hr, and at 500°F retain elasticity for more than 250 hr. Parts have been tested for shorter periods at 700°F and been found serviceable.

One producer of high temperature silicone lubricants has recently announced that Viton A was used successfully as an "O" ring seal at 400°F.

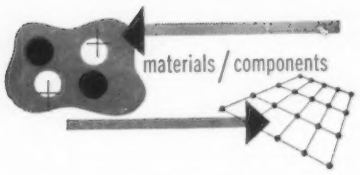
DuPont Elastomers Div.

Circle 224 on postcard for more data

Hot-Melt Adhesive Eases Small Parts Assembly

Ray-Bond R-84001, a hot-melt adhesive provides instant grab when applied to glass, etched Teflon, Mylar, polystyrene, polyethylene, and other materials difficult to bond. It is being used to simplify assembly line operations by holding small parts in place until they can be permanently fastened.

The adhesive may also be used as a permanent binder up



to 150°F. A one-square inch lap joint made on Mylar will hold a dead load of 50 pounds at 73°F, and a load of six pounds at 150°F.

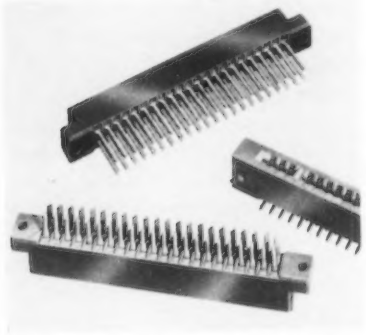
Composed entirely of solids, the adhesive is supplied in a semi-brittle state. It is liquefied by heating to 250°F and applied in the fluid state to one of the parts to be assembled. The other part is immediately pressed into contact, and the two held together until the adhesive cools. The strength of the bond increases as the adhesive cools to room temperature.

Raybestos-Manhattan, Inc.

Circle 225 on postcard for more data

Printed Circuits Use One-Piece Receptacles

Printed circuit board receptacles are now of one-piece body construction and available



in either type GR and MFE mineral filled phenolic, MDG diallyl-phthalate or CFG general purpose phenolic. The board receptacle series have a new contact design to prevent board-to-contact damage. Contact material is beryllium copper, standard plating is gold over silver. Nylon polarizing keys permit quick interchangeable polarizations.

H. H. Buggie, Inc.

Circle 182 on postcard for more data

Liquid Phenolic Adhesive Exceeds Spec Requirements

A modified phenolic liquid adhesive will produce shear strengths in excess of those required for structural bonding by military specification (MIL-A-5090 B).

This modified phenolic liquid adhesive has good peel strength and good heat resistance up to 180°F. It maintains its high strength properties over a service temperature range of —65 to 180°F. It is used to bond metal facings to honeycomb core material in the production of honeycomb sandwiches.

Filleting properties are better than nitrile phenolic adhesives but are less effective in this respect when compared with most epoxy compounds. Peel strengths on bonded honeycomb structures are superior to those obtained with epoxies but lower than those obtained with nitrile phenolics.

A bond with room temperature shear strengths of 5300 psi, exceeding the requirements of military specification MIL-A-5090 B, is obtained by curing adhesive EC-1471 for 45 minutes at 350°F under a pressure of 50 to 200 psi.

Longer cures will produce high elevated temperature strength properties. For example, after curing for 2 hours at 350°F and under a pressure of 50 psi, a typical aluminum joint bonded with the adhesive has a 180°F service temperature shear strength of 4000 psi. Cures as short as 30 minutes at 325°F will produce strengths sufficient for many applications.

Metal surfaces must be chemically cleaned to sustain a continuous water film.

For metal-to-metal bonding a 3 to 4 mil dry-film thickness of adhesive EC-1471 is applied to each surface. If the adhesive is applied in multiple coats, a 30 min air drying period should be allowed between and after each coating. A force dry of 20 min at 250°F should follow each air drying procedure.

When used as a honeycomb sandwich adhesive, an 8 to 10 mil dry-film thickness of adhesive is applied to both facings and core by roller, brush, spray, or coating methods. The multiple coating procedure is the same as that for metal to metal bonding.

Circle 226 on postcard for more data

Minnesota Mining and Mfg. Co.

Direct Reading Dials Indicate Temperatures

A temperature measuring system now offered for aircraft flight testing provides direct-reading dial indication of stagnation temperature ranging from —60°F to 1000°F.

A typical system, the FT-104, consists of a resistance thermometer, control unit with a temperature-controlled silicon diode reference, bridge circuits, and a chopper type servo millivoltmeter for display purposes. Indicator dials are individually

calibrated or "keyed" to the particular temperature sensor and control unit being used.

Additional indicators can be slaved to the master indicator to provide multiple outputs. Recording oscillographs can also be given from the master indicator.

North Atlantic Industries, Inc.

Circle 199 on postcard for more data

Continued on page 69

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MATERIALS & COMPONENTS

Alphabetical List of Products

225 **Adhesive, hot-melt**
Raybestos-Manhattan, Inc.

226 **Adhesive, liquid-phenolic**
Minnesota Mining & Mfg. Co.

203 **Barrier, vapor**
American Chemical Paint Co.

208 **Beacon, identification, radar**
Stavid Engineering, Inc.

188 **Ceramoplastics, thin molding**
Mycalex Corp. of America

187 **Domes, infrared-transmitting**
Servo Corp. of America

224 **Elastomer, heat-resistant**
E. I. du Pont de Nemours, Inc.

192 **Fastener, spring-pin**
Standard Pressed Steel Co.

191 **Generator, hydraulically-actuated**
Sundstrand Machine Tool Co.

190 **Insulation, flexible fiber glass**
Safpac Corp.

194 **Liner, abrasion-resistant**
Kennametal, Inc.

182 **Receptacles, printed-circuit**
H. H. Buggie, Inc.

212 **Rejection unit, quick-acting**
John Oster Mfg. Co.

184 **Relay, miniature**
Union Switch & Signal Co.

199 **Temperature measuring system**
North Atlantic Industries, Inc.

185 **Tubes, laminated**
Silicone Insulation, Inc.

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Village Station,
New York 14, N. Y.

Readers Service Dept.

WORTH ASKING FOR

230
Electronic components

order your new subscription now!

191 **Sundstrand Machine Tool Co.**
Generator, hydraulically-actuated
184 **Union Switch & Signal Co.**
Relay, miniature

NEW FOR PRODUCTION
Alphabetical List of Products

133 **Compressor, portable**
Davey Compressor Co.
261 **Detector, radiation**
Nuclear Measurements Corp.
264 **Index table, electronic-control**
Superior Machine & Engineering Co.
132 **Power supply, germanium-rectifier**
Opad Electric Co.
259 **Pump, glassed-metal**
Goulds Pumps, Inc.
262 **Rivet, steel, blind**
Huck Manufacturing Co.
263 **Screws, miniature**
Voi-Shan Manufacturing Co.
258 **Switch, pressure, low-differential**
Meletron Corp.
257 **Torque clutch, tapping attachment**
Tapmatic Corp.
265 **Torque limiter**
Livermont, Inc.
260 **Valves, fuel, diaphragm-operated**
Sinclair-Collins Valve Co.
146 **Valve, selector, pneumatic**
Aircraft Products Co.

Alphabetical List of Companies

146 **Aircraft Products Co.**
Valve, selector, pneumatic
133 **Davey Compressor Co.**
Compressor, portable
259 **Goulds Pumps, Inc.**
Pump, glassed-metal
262 **Huck Manufacturing Co.**
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Switch, pressure, low-differential
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Valves, fuel, diaphragm-operated
264 **Superior Machine & Engineering Co.**
Index table, electronic-control
257 **Tapmatic Corp.**
Torque clutch, tapping attachment
263 **Voi-Shan Manufacturing Co.**
Screws, miniature

MARCH 1958

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Specific Products Manufactured

MARCH 1958

new Subscription Order

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Specific Products Manufactured

Postcard valid 8 weeks only. After that use own letterhead fully describing item wanted. **MARCH 1958**

Please send further information on items circled below.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
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281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300

YOUR NAME ..... TITLE .....

COMPANY .....

PLANT ADDRESS .....

CITY ..... ZONE ..... STATE .....

WORTH ASKING FOR

Alphabetical List of Items

240
Contaminates, safe handling
S. Blickman, Inc.

229
Coupling, flexible
T. B. Wood's Son's Co.

230
Electronic components
Heremetic Seal Transformer Co.

296
Electronics, manufacturing capabilities
Lear, Inc.

234
Electronics, products and systems
Western Design & Mfg. Co.

231
Fastener
Hi-Shear Rivet Tool Co.

272
Gas welding
Modern Engineering Co.

273
Hose assemblies
Resistoflex Corp.

235
Lathes, accessory equipment
The Monarch Machine Tool Co.

268
Machines, planishing and welding
Airline Welding Sales, Inc.

266
Manufacturing, contract
Darco Industries, Inc.

267
Metals, cold flowing
Claude C. Slate Co.

232
Metal finishing, precision
Roto-Finish Co.

239
Polyester, molding compound
Atlas Powder Co.

237
Printing, offset machines
Jas. H. Matthews & Co.

236
Relays, miniature
Radio Corp. of America

269
Ring, slip, assemblies
Slip Ring Co. of America

274
Springs, Belleville
Union Spring & Mfg. Co.

233
Spring, design
Associated Spring Corp.

228
Tapes, pressure-sensitive
Minnesota Mining & Mfg. Co.

238
Thermoswitch, temperature control
Fenwal Inc.

297
Tubing, metal joint
Aeroquip Corp.

270
Valves, air, oil, water
Barksdale Valves

FIRST CLASS
PERMIT No. 18
Philadelphia 39, Pa.

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No Postage Stamp Necessary if Mailed in the United States

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Aircraft and Missiles Manufacturing

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Aircraft and Missiles Manufacturing

CHESTNUT & 56TH STS.

PHILADELPHIA 39, PA.

FIRST CLASS
Permit No. 36
New York, N. Y.

BUSINESS REPLY CARD
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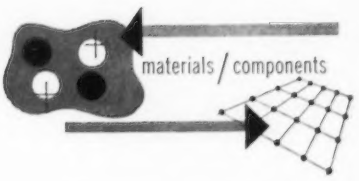
POSTAGE WILL BE PAID BY

Aircraft and Missiles Manufacturing
P. O. Box 74,
Village Station,
New York 14, N. Y.

Readers Service Dept.



Continued from page 64

Tungsten Carbide Used For Abrasion Resistance

Tungsten carbide can be cemented to metallic and non-metallic surfaces to provide

hard facing for protection against abrasion and wear.

The new tungsten carbide material consists of small hexagonal plates cemented in a continuous pattern on an adhesive glass fiber backing to provide flexible sheets or strips for application on flat or curved surfaces. The adhesive backing holds the small plates in position while they are being bonded by epoxy adhesives, silver solder, or conventional brazing materials. The good wear-resistance properties of hard tungsten carbide are imparted to the covered surface.

The flexible backing simplifies application since the basic sheets can be cut or joined in multiples to cover flat or curved surfaces.

Kennametal Inc.

Circle 194 on postcard for more data

Subminiature Identification Radar Beacon Developed

An airborne radar beacon with a 2½-in. diam and weighing 6 lb has been developed for use on the North American X-15.

The beacon receives single-pulse transmissions from tactical radar sets and develops a coded pulse reply for transmission back to the radar. The coded reply is used by the radar operator to track and/or identify the aircraft.

Stavid Engineering

Circle 208 on postcard for more data

Compressed Fiber Glass Flexible Insulation Eliminates Preforming

Saflex, a flexible aircraft insulation material has good impact strength and requires no pre-forming. The material consists of compressed glass fibers which are oriented to provide maximum resiliency and to eliminate voids.

A patented corrugating process provides the 360 deg flexibility feature. Saflex is available to a wide range of specifications which withstand temperatures up to 1000° F.

Safpac Corp.

Circle 190 on postcard for more data

Infrared Transmitting Domes Made With 12 in. Diameter

Servofrax, an arsenic trisulphide glass, may be molded,

ground, and polished to produce one-piece domes.

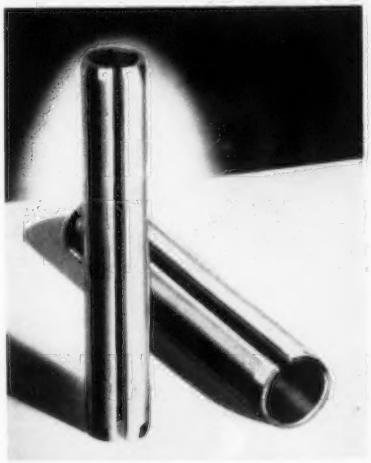
Used in transmitting infrared radiation to detection equipment, this shape is available in sizes from 4 to 12 in. dia and up to an 180 deg arc (hemisphere).

Servo Corp. of America

Circle 187 on postcard for more data

Spring Pin Fasteners Are Non-Sparking

Self-locking, spring-pin fasteners now made of beryllium copper, add non-sparking,



non-magnetic, and high conductivity properties to the Sel-Lok "vibration-proof" fastener.

Beryllium-copper spring pins are made in nominal diamter sizes ranging from 0.062 to 0.250 in. Lengths range from 3/16 in. to 4 in.

Hardness is Rockwell "C" 36 to 42. Minimum shear strengths are approximately 60 per cent those of standard carbon steel spring pins.

Standard Pressed Steel Co.

Circle 192 on postcard for more data

Chemical Blanket Reduces Escape of Vapors in Phosphate Baths

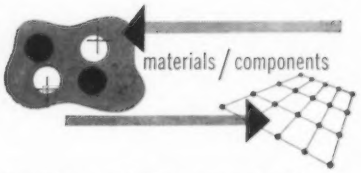
Serseal a chemical blanket for use on hot phosphate coating baths acts as a barrier to escape of steam and fumes.

Heat savings up to 70 per cent have been reported in actual field use. Serseal has also shown reductions in the cost and time required for maintenance of heating elements. Since the phosphate bath is sealed by the new blanket, there is little escape of fumes and vapors and, in some cases, costly ventilating systems are not necessary.

American Chemical Paint Co.

Circle 203 on postcard for more data

Continued on next page

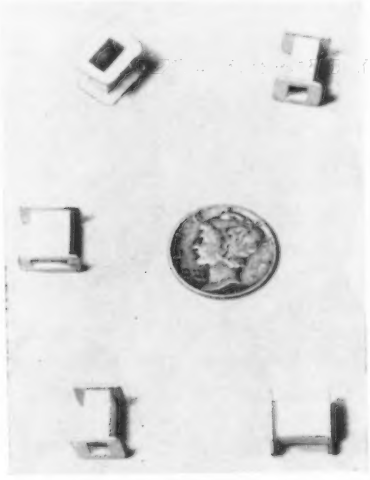


Molding of Ceramoplastics To 0.001 in. Tolerances

Improved molding techniques with Supramica have made possible ceramoplastic sections as thin as 0.018 in., to tolerances of 0.001 in. This offers new possibilities to designers of miniature components for high-temperature applications.

Mycalex Corp. of America

Circle 188 on postcard for more data



Quadrature Rejection Unit Operable Over Wide Range of Temperatures

A hermetically sealed quadrature rejection unit that

instantly achieves 90 per cent of full speed when energized at −60°C has been developed. The 22 rpm minimum speed at rated voltage varies about ±10 per cent over the entire operating range of −60 to 80°C.

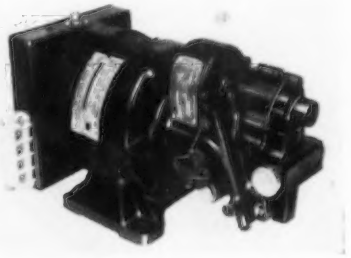
When properly excited the output is an ascending saw tooth voltage. Motor voltage is 26 v, 400 cyc, 2 phase.

John Oster Mfg. Co.

Circle 212 on postcard for more data

Generator System Powered By 4 kva Hydraulic Motor

A new 400-cycle missile, emergency and isolated electrical power-generating system powered by a controlled-speed hydraulic motor and rated at 4 kva with 100 per cent overload,



is operable at a temperature of 65° to 275°F.

The unit weighs 34.5 lbs.

Sundstrand Machine Tool Co.

Circle 191 on postcard for more data

SPEED SENSITIVE SWITCHES

1, 2 and 3 ELEMENT

UNDERSPEED . . . One S.P.D.T. switch to trip at speeds as low as 400 RPM. Maximum operating speed 5,000 RPM.

OVERSPEED . . . One S.P.D.T. switch to trip at speeds between 500 and 6,000 RPM.

OVER AND UNDERSPEED . . . Two S.P.D.T. switches to trip at two different speeds between 500 and 6,000 RPM.

OVER—INTERMEDIATE AND UNDERSPEED . . . Three S.P.D.T. switches to trip at three different speeds between 1,200 and 6,000 RPM.

Speeds above or below those listed above must be referred to our Engineering Department for special consideration. Request Bulletin 504 describing our Speed Sensitive Switches.

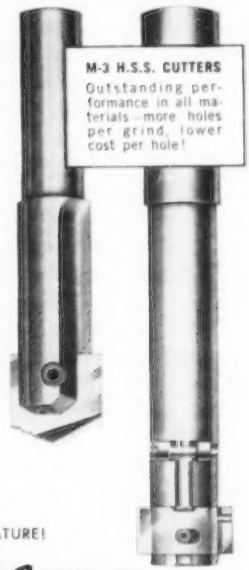
SYNCHRO-START PRODUCTS, INC.
8151 N. RIDGEWAY AVE., SKOKIE, ILLINOIS
Automatic Engine Control Sets • Special Control Panels • Safety Alarm Sets • D.C. Solenoids • Heavy Duty Relays

Circle 114 on Inquiry Card, page 65

New Clark TOOLS SOLVE HOLE MAKING PROBLEMS

CLARK SPADE DRILLS
for lower cost per hole!
Easily reground to smaller diameters. Shanks drilled for coolant circulation. Straight or Morse tapers. Standard sizes $1\frac{1}{16}$" to 5", other sizes on order. Prompt delivery!

CLARK adjustable FINISHING & ROUGHING BARS with new CAM LOCK
Free floating action, instant blade removal without destroying the set-up. Sizes: Finishing $\frac{5}{8}$" to 6"; Roughing 1" to 6". Straight shank or Morse tapers. Other sizes on order.



WRITE FOR LITERATURE!

Robert H. Clark Company
9330 Santa Monica Blvd., Beverly Hills, California

Circle 115 on Inquiry Card, page 65

worth asking for:

technical literature listed here is available without charge from the various manufacturers

Pressure Sensitive Electrical Tape

Application information and specifications for a complete line of pressure sensitive electrical tapes and epoxy resins for electrical insulations are listed in a 32-page guide book and catalog.

Minnesota Mining & Mfg. Co.

Circle 228 on postcard for more data

Flexible Couplings

An eight-page, letterhead-size, two-color bulletin tells how to select Sure-Flex couplings suited to more than 150 different service applications. Five tables short-cut the usual engineering calculations and give the right answer in a matter of seconds, taking into consideration the type of driver, horsepower, and rpm; as well as the specific application.

T. B. Wood's Son's Co.

Circle 229 on postcard for more data

Electronic Components

Listed, illustrated, and described in 1958 catalog No. 102, are 390 stock and many special-application audio transformers, chokes, filters, geophysical transformers, high-temperature transformers and reactors, magnetic amplifiers, miniature transformers, power transformers, pulse transformers, reactors, space-saver audio units, toroids, and transistor transformers.

Hermetic Seal Transformer Co.

Circle 230 on postcard for more data

Threaded Fastener

A four-page brochure describes Hi-Lok fastener advantages, gives technical details, and discusses tooling.

Hi-Shear Rivet Tool Co.

Circle 231 on postcard for more data

Precision Metal Finishing

A 24-page four-color catalog on precision metal finishing, by mechanical barrel-finishing methods, answers some of the basic questions to the problem of achieving large-quantity production runs while maintaining exact tolerances and uniformity of finish.

Roto-Finish Co.

Circle 232 on postcard for more data

Spring Design

The best design practice to get successful spring performance is early consultation and close cooperation between the product designer and the spring-manufacturing specialist. This premise is persuasively put forward in a 12-page brochure entitled *How to Solve Your Spring Design Problems.*

Associated Spring Corp.

Circle 233 on postcard for more data

Electronic Systems

A 46-page brochure sets forth the design, engineering, and manufacturing facilities, and shows typical electro-mechanical and electronic products and systems in the fields of power supplies, actuators, blowers, timing devices, and inverters as used in the manufacture of aircraft and missiles.

Western Design & Mfg. Co.

Circle 234 on postcard for more data

Engine Lathes

A 32-page illustrated bulletin (No. 1506) describes Series 62 lathes, twelve models in all. Complete description and photographs of an extensive array of accessory equipment, including contour controls and air-gage tracer system, also are presented.

The Monarch Machine Tool Co.

Circle 235 on postcard for more data

Subminiature Relays

A broad range of over 325 subminiature relays meeting and excluding Mil-5757A, B & C, and Mil-R-25018 (USAF) are described in a new 12-page booklet amply illustrated with photographs, diagrams, and complete descriptions of relays including contact and vibration ratings.

Radio Corp. of America.

Circle 236 on postcard for more data

Product Marking Machines

A five-page booklet describes the function and specifications of five different offset printing machines for product

worth asking for:

technical literature listed here is available without charge from the various manufacturers

Continued from page 71

marking on surfaces of steel, plastic, aluminum, and others.

Jas. H. Matthews & Co.

Circle 237 on postcard for more data

Temperature Controls

"Got a Temperature Control Problem?" is the title of a four-page folder describing how a Thermoswitch unit can help equipment to run at faster speeds, require less maintenance, and have longer life and reduced assembly costs. Also included are complete construction details of the control and six basic design configurations.

Fenwal, Inc.

Circle 238 on postcard for more data

Polyester Molding Compounds

A paper-bound 40-page catalog describes Atlas Thermaflow reinforced polyester molding compounds.

Catalog features detailed data sheets on each of seven compounds. Characteristics such as form and shelf life are given, as well as the physical, chemical, mechanical, and heat and flame resistant properties of the molded part under ASTM procedures.

Atlas Powder Co.

Circle 239 on postcard for more data

Safe Handling of Contaminants

A 12-page folder recently published by S. Blickman, Inc., illustrates some twenty-six different technical enclosures for the safe handling of all types of contaminants.

S. Blickman, Inc.

Circle 240 on postcard for more data

Contract Manufacturing

A six-page brochure indicates services offered in design and development, assembly production, contour machining, and specialized metal fabrication and welding.

Plant security, transportation facilities, employees, modern equipment, scheduling, and quality control are described.

Darco Industries, Inc.

Circle 266 on postcard for more data

Flotrusion

This fabricating process for cold flowing various metals into tubular forms of all sizes and shapes has been named Flotrusion. Advantages of this process over machining are pointed out.

Claude C. Slate Co.

Circle 267 on postcard for more data

Planishing and Welding Machines

Longitudinal, circumferential, and combination planishers and automatic welding machines are described in a four-page brochure. The welders have automatic chucking, travel, and ejection. Units can be used with any welding process.

Airline Welding Sales, Inc.

Circle 268 on postcard for more data

Slip Ring Assemblies

Over 50 slip rings, brushes, commutators, and drums are pictured. Nine methods of manufacturing these units are disclosed along with the different materials and end uses of the product.

Slip Ring Co. of America

Circle 269 on postcard for more data

Valve Catalog

This 56-page catalog provides comprehensive characteristics and data to aid in the selection and application of valves for air, oil, and water.

Contains simple graphs determining means of calculating pressure drop, discharge and velocity of liquids, with a pressure conversion chart scaled from zero to 3000 psi. Also summarizes probable causes and remedies for the more difficult maintenance problems.

Barksdale Valves

Circle 270 on postcard for more data

Gas Welding

A 36-page revised catalog No. 160 announces "Meco" oxyacetylene welding and cutting equipment covering recommended applications of cutting torches, air-acetylene torches, machine cutting torches, regulators, couplings, adaptors, hose connections, and safety instructions.

Modern Engineering Co.

Circle 272 on postcard for more data

Hose Assemblies

A new 64-page handbook on fluorocarbon flexible hose and hose assemblies is being offered to engineers and designers in the missile and aircraft industry. Technical data, including specifications and working drawings, on corrosion resistant and chemically inert Fluoroflex-T high temperature hose assemblies are included.

Resistoflex Corp.

Circle 273 on postcard for more data

Belleville Springs

A 16-page new technical brochure shows various end uses and gives data that Design Engineers will find useful. Included are nomenclature, formulae for load-deflection curve springs and constant load type springs, tolerances, and information on aluminum as well as copper bus bar applications.

Union Spring and Mfg. Co.

Circle 274 on postcard for more data

Electronics Plant Facilities

A 12-page, 40-photograph brochure, provides detailed facts and figures on electronics "Engineering and Production Capabilities."

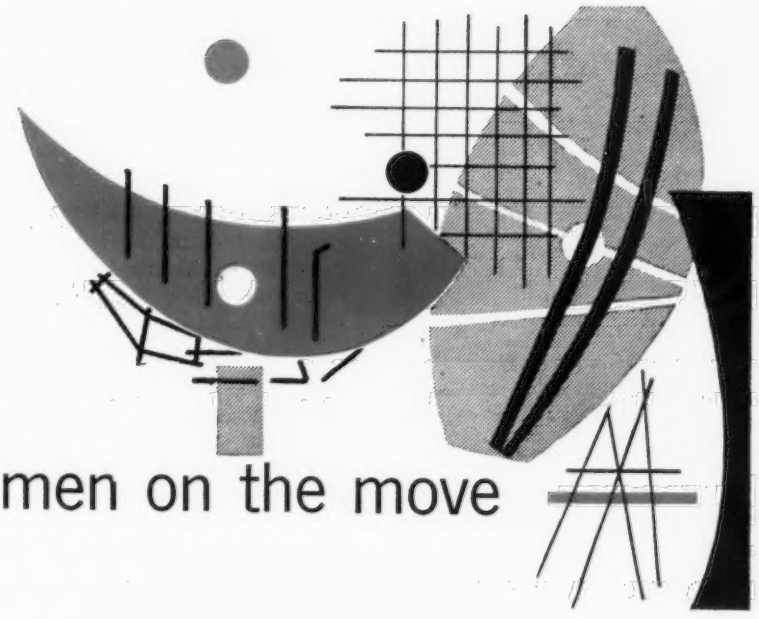
Lear, Inc.

Circle 296 on postcard for more data

DR. FRED P. ADLER
Hughes Aircraft

DR. ALBERT C. HALL
Martin

TIM J. BUCKLEY
Nylok



men on the move

DR. FRED P. ADLER has been promoted to manager of the advanced planning staff for the systems development laboratories of Hughes Aircraft Co., Culver City, Cal.

DR. ALBERT C. HALL, scientist and founder of the Dynamic Analysis and Control Laboratory at The Massachusetts Institute of Technology, has been named director of research for The Martin Co.

TIM J. BUCKLEY has been named vice-president and general sales manager of the Nylok Corp.

J. E. (NED) JOHNSON has become vice-president of production.

CARL E. BORNER has been appointed vice-president of engineering.

JOHN D. KOHLER has been promoted to assistant manager of aircraft and missiles sales for Flexible Tubing Corp., Guilford, Conn.

EDWARD G. MERK has been selected as national sales manager for Burgmaster Corp., Gardena, Cal.

LEE MOULTON has been named manager of field engineering training for the Electro-Data Div. of Burroughs Corp.

LELAND W. BROWN has been appointed Los Angeles district field-engineering manager.

GEORGE A. KENDALL, chief engineer of Wickes Corp. Machine Tool Div., Saginaw, Mich., has been appointed divisional president and general manager.

J. EARLY HARDESTY has been elected vice-president and treasurer of the Black and Decker Mfg. Co.

GEORGE W. MC CARTY was elected vice-president of research and development.

GEORGE A. DE CARIO has been appointed district field service manager of the northern Ohio area, which includes western Pennsylvania, for Wagner Brothers, Inc., Detroit.

DARREL C. KARL has been promoted to operations manager of Inland Testing Laboratories, a division of Cook Electric Co., located in Morton Grove, Ill.

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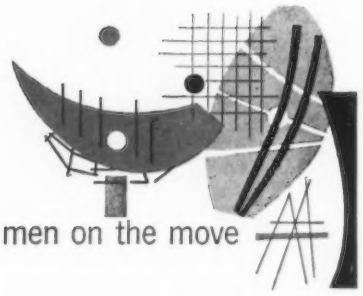


DR. JOSEPH V. PETROCELLI has been appointed head of the electrochemical section of the International Nickel Co. research laboratory at Bayonne, N. J.

HILLIARD W. PAIGE has been appointed manager of the nose cone section in General Electric Co. missile and ordnance systems department at Philadelphia.

ROBERT P. FOPEANO has been chosen supervisor in charge of the New York district office for the Computer div. of Bendix Aviation Corp.

HARRY A. HILLMAN has been named assistant for personnel to John Myers, president of Westinghouse Electric Supply Co.

WILLIAM A. STEWART has been named chief project engineer for the Behlman Engineering Co., Burbank, Cal.

G. WILLIAM LOVEDAY has been advanced to assistant manager of industrial component sales for Flexible Tubing Corp., Guilford, Conn.

PETER KUNTZ has rejoined The Gevaert Co. of America, Inc., as industrial X-ray technician for the Eastern United States.

RUSSELL C. FLOOD has been appointed general operations manager with over-all responsibility for the U. S. plant of the Schrader Div. of Scovill Mfg. Co.

JAMES H. MOORE has been named general manager of NRC Equipment Corp., a subsidiary of National Research Corp.

HARRY D. STONE has been appointed sales manager.

HERBERT E. ELLIOT is now associated with Loewy-Hydropress Div., Baldwin-Lima-Hamilton Corp., New York.

HAROLD R. SENNSTROM has assumed responsibility for all American Bosch Div. sales operation and has been appointed vice-president of engineering and sales.

JOHN. M. NISBET has joined Philco Corp., Government and Industrial Div., as sales manager of the "Transac" computer department.

WILLIAM BUHL has been selected to head commercial sales for Chromalloy Corp., White Plains, N. Y.

JOSEPH H. CADIEUX has been named vice-president of Casting Engineers Inc., Chicago.

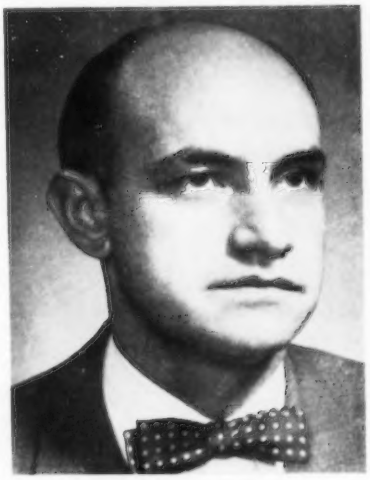
CHARLES H. JACKSON has been added to the staff of the electronics dept. of Hamilton Standard, Broad Brook, Conn., as a project engineer in the advanced design group.

NEIL E. FIRESTONE has been appointed general manager of the General Electric Co. production engine dept. with headquarters in Evendale, O.

PAUL E. LORENTZEN has been made manager of the Magnetics Div. of the Networks Electronic Corp., Van Nuys, Cal.

IRWIN A. BINDER has been appointed vice-president for manufacturing of The Ramo-Wooldridge Corp. of Los Angeles, a Thompson Products affiliate.

JAMES H. MOORE
NRC Equipment Corp.



JOSEPH H. CADIEUX
Casting Engineers, Inc.

IRWIN A. BINDER
Ramo-Wooldridge

industry notes

Science Breaks Through Insulation Barrier

A major scientific "breakthrough" has been achieved by scientists at Johns-Manville Research Center by their development of a unique aviation insulation, according to Dr. Clifford F. Rassweiler, vice president for research and development.

Called Min-K because of its minimum conductivity, the material is expected to be of prime importance in rockets, missiles, and jet aircraft. The manufacturer claims the material has lower thermal conductivity than any other known insulating material.

Conservation of critical space through the use of this material provides as much as 20 per cent more space within the rocket for fuel, therefore, provides for increased range.

More efficient protection of temperature-sensitive instruments and controls should result in greater directional accuracy for American rockets and missiles.

An outstanding characteristic of the material is that its insulating qualities increase as atmospheric pressure decreases. The higher the rocket flies, the better the insulation performs.

It can be laminated into structural shapes and is readily moldable. Production contracts for a rocket tail section and supersonic fighter are now being filled.

Mobile Storage Racks Made From Steel Scrap

To cut down costs, industry is always on the lookout for new ways to salvage scrap material. Boeing Airplane Co., Seattle, built up several of these handy storage racks from scrap

material for use in its huge flight test hangar.

The racks are made from surplus 55-gal steel drums and lengths of steel pipe. Drums were cut in half, the edges rolled, and the sections welded to the steel pipe columns in the pattern shown here. Steel scrap formed the base. Castors and a coat of paint completed the job.

Boeing utilizes these racks for storing hydraulic hose used in various airplane functional testing. Electrical wire harnesses can be stored equally well. A little ingenuity might suggest countless uses for these portable storage racks. Their cost is negligible.

Portable Reactor Proves Successful in Test

A self-sustaining nuclear reaction in the reactor core of the Martin "package power reactor" at the company's zero power test facility has been accomplished.

The reaction was attained with a core loading of approximately 700 stainless steel clad, enriched uranium fuel tubes.

This is the furthest advance in the concept of building an "all-climate" nuclear power plant in a self-contained package (approximately 9 x 9 x 30 ft and weighing 6 to 15 tons).

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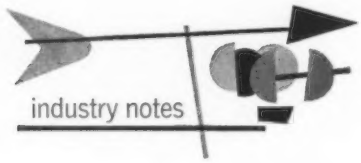


INDUSTRY STATISTICS

Source: Bureau of the Census and Civil Aeronautics Administration.

VALUE OF SHIPMENTS OF AIRCRAFT PROPELLERS AND PARTS

All data are in Thousands of Dollars

	Total All Products	For Military Aircraft	For Civilian Aircraft	Other Products†
First Quarter	$ 51,079	$ 20,767	$ 11,599	$ 18,713
Second Quarter	60,772	27,065	11,483	22,224
Third Quarter	66,194	31,658	7,836	26,700
Fourth Quarter	72,140	41,117	10,800	20,223
Total—1957	$250,185	$120,607	$ 41,718	$ 87,860
First Quarter	$ 40,343	$ 21,520	$ 6,430	$ 12,393
Second Quarter	45,014	21,639	7,837	15,538
Third Quarter	40,502	17,835	7,744	14,923
Fourth Quarter	59,939	26,217	9,766	23,956
Total—1956	$185,798	$ 87,211	$ 31,777	$ 66,810

† Includes experimental work.

SHIPMENTS OF PROPELLERS

for Civilian Aircraft

Month	Number of Propellers 1957	1956
January	1,148	1,060
February	1,403	1,014
March	1,629	1,199
April	1,475	1,196
May	1,572	1,273
June	1,419	1,375
July	1,120	979
August	1,192	947
September	1,152	1,035
October	1,338	1,097
November	1,372	974
December	1,194	808
Total	16,014	12,957

NUMBER AND VALUE OF CIVIL AIRCRAFT SHIPMENTS

Month	Units 1957	1956	Value in Thousands 1957	1956
January	584	537	$ 48,431	$ 22,325
February	523	614	49,278	32,139
March	665	656	46,465	29,562
April	642	692	57,723	30,229
May	662	714	83,965	35,145
June	580	648	69,326	40,270
July	515	507	70,480	32,280
August	509	681	62,825	46,294
September	456	613	54,745	41,137
October	464	508	45,522	50,089
November	511	472	47,130	51,518
December	545	563	44,854	43,168
Total—Year	6,656	7,205	$680,744	$454,156

AIRFRAME WEIGHTS OF CIVIL AIRCRAFT SHIPMENTS

Month	Thousands of lbs. 1957	1956	Avg./Aircraft 1957	1956
January	1,574.9	986.2	2,697	1,837
February	1,554.0	1,265.4	2,971	2,061
March	1,615.6	1,200.4	2,429	1,830
April	1,871.6	1,227.1	2,915	1,773
May	2,548.0	1,362.2	3,849	1,908
June	2,104.0	1,460.8	3,628	2,254
July	2,086.0	1,162.3	4,051	2,293
August	1,940.6	1,600.7	3,813	2,351
September	1,631.1	1,389.2	3,577	2,266
October	1,446.3	1,583.6	3,117	3,117
November	1,475.8	1,550.7	2,886	3,285
December	1,431.4	1,413.7	2,626	2,511
Total—Year	21,279.3	16,202.3	3,197	2,249

SHIPMENTS OF PISTON ENGINES FOR CIVILIAN AIRCRAFT

Month	Units 1957	1956	Value 1957	1956
January	920	930	$ 12,445,000	$ 6,800,000
February	902	976	13,596,000	6,923,000
March	1,010	1,065	13,975,000	7,600,000
April	950	949	14,388,000	7,967,000
May	1,020	1,038	15,160,000	9,459,000
June	933	977	15,636,000	8,682,000
July	801	996	12,748,000	8,420,000
August	776	1,037	8,603,000	8,036,000
September	728	793	10,150,000	9,938,000
October	921	902	13,638,000	10,877,000
November	878	911	9,880,000	11,391,000
December	1,020	925	12,237,000	12,370,000
Total—Year	10,859	11,499	$152,456,000	$108,263,000

TOTAL HP. OF AIRCRAFT PISTON ENGINE SHIPMENTS FOR CIVILIAN USE

Month	Total Hp. (in thousands) 1957	1956	Avg. Hp. per Engine 1957	1956
January	604.4	383.3	657	412
February	647.0	401.3	717	411
March	679.2	431.7	672	405
April	668.2	431.4	703	455
May	715.8	503.5	702	485
June	730.4	459.4	783	470
July	590.4	444.6	737	446
August	425.6	431.8	548	416
September	482.8	481.0	663	607
October	628.3	536.0	661	594
November	473.0	556.6	539	611
December	586.2	595.6	575	644
Total—Year	7,231.3	5,656.2	666	492

Measurement Activities in the U.S.S.R.

Excerpt from a talk by A. V. Astin, Director, National Bureau of Standards

Soviet leaders have repeatedly emphasized that their major competitive objective is to overtake and excel the capitalistic nations in production per capita. The Russians' announced intention to compete in this area should be of immediate interest to all American industrial leaders because if we are successful in our efforts to maintain world peace, we will most certainly continue to be confronted by their challenge to excel us in terms of industrial productivity. Although we now excel the Russians substantially in our production of consumer goods we should not be lulled into believing that their technological base is not capable of being developed for such production if their leaders should so decree. The fact that they have surprised us with their ability first to build an A bomb and then an H bomb more quickly than we had expected and more recently to launch the first earth satellite should be ample warning that the technological foundation from which these achievements evolved is a very substantial one.

Increases in Productivity

Most of the information I have on this subject comes from the Russian journal *Measurement Engineering*, the official organ of the Committee on Standards, Measures and Measurement Apparatus of the Council of Ministers of the U.S.S.R. Articles in this journal point out that the major objective of the 6th Five-year Plan, which began in 1956, is to increase their means of production by approximately 70 per cent and their output of consumer goods by approximately 60 per cent. During this period there are expected to be substantial increases in the output of basic materials and an increase in the output of their machine tool industry by approximately 80 per cent. Fundamental to these increases in productivity the Plan calls for extensive expansion of their instrumentation industry. All types of electrical, mechanical, optical, radiation measuring instruments and related instruments for automation will be increased by substantial amounts, averaging about 300 per cent.

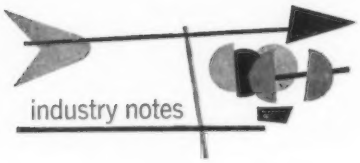
Calibration Centers

The entire program of instrument development and production, as well as the means of utilizing effectively their new instruments is under a Committee on Standards, Measures and Measurement Apparatus of the Council of Ministers of the U.S.S.R. Five research institutions work directly for this Committee on new and improved techniques for physical measurement and on the development and maintenance of the basic standards for measurement. Operating under the supervision of the institutes is a network of calibration centers. Their Plan calls for 129 such centers by 1960. A major function of these calibration centers is to evaluate and approve all of the measuring instruments used in any Russian production plant. One of the available reports includes an item chastizing industry for not measuring up to new precision standards and urging that greater authority be lodged in the regional calibration centers so that they will not only pass on the precision characteristics of the instruments but also upon the way they are used in industrial plants. Another function of the calibration centers is to make available to industry the latest advances on new measurement techniques derived from the research institutes. This is indeed a substantial chain to insure not only that new measurement techniques are developed and made available but also that they are used effectively.

Plans for Automation

One series of papers reporting on the results of a Standards and Measurement Conference held in March 1956 reveals that a sizeable and high order of technical investment is being made in these areas. The conference dealt principally with standards and measurements as they applied to the machine production industry. More than 500 delegates, including research personnel, were in attendance. The conference, lasting 4 days, took up some of the most advanced problems in measurement research, problems which indicated the high degree of precision which the Russians were seeking to obtain. Sections were devoted to production precision, interchangeability, and engineering measurement. Special attention was given to the problem of advancing the art of measurement so that it would have a direct impact on Soviet plans for automation. Their discussions of this part of the program reveal a profound understanding and extensive effort on the relationship of precision in the automation of production processes.

The reports also indicate a practical approach to the efficient utilization of varying degrees of precision. Most metrologists are familiar with all too many instances where extreme tolerances have been imposed



unnecessarily with resulting cost increases and inefficiencies. This usually comes from a lack of appreciation of measurement problems by specifications writers. The Russians through a systematic method of classification and application of varying degrees of precision in their instruments and their use, coupled with thorough education and training, seem to have this problem well in hand.

Measurement Competence

A description of their exhibits at the Standards and Measurement Conference reveals appreciable information on the level of their measurement competence. We are now in the process of comparing some of their levels of achievement with our own but one area in particular is quite startling. This deals with their competence to make calibrations of temperature measuring devices. In 1956 they claimed to be prepared to make calibrations of temperature measuring devices up to 6000°C and their Five-year Plan calls for extending this competence to 12,000°C by 1960. At the National Bureau of Standards we have reasonably satisfactory means for providing temperature calibrations only to 2800°C. We have on occasion extended such calibration by impromptu means to 4200°C, but our capability for this and higher temperatures is severely restricted by lack of means of producing high temperatures, since our best high temperature producing device is a small solar furnace capable of attaining temperatures of about 3500°C. The Russians' interest and competence in making measurements at such high temperatures is indicative, I believe, of a very substantial effort by them in development activities in this very important technological frontier, which is relevant to such things as high energy fuels.

Inferences to Be Drawn

Although our knowledge of some of these Russian activities is still somewhat sketchy, it is possible to draw certain inferences: (1) the program for standards and precision measurement is apparently operated from a higher governmental level than any other industrial activity in the U. S. S. R. (2) The investment in these areas is extremely large and seems to be especially directed toward fulfilling the precision requirement of complex automatic machine production for intended automation of large segments of the U. S. S. R. industry. (3) There appears to be a clear tendency to lean heavily on theoretical analysis of technological problems and in encouraging research and development programs in the instrumentation of precise measurement. (4) There is a program to inculcate cooperative technological efforts among relevant branches of the economy, including the Ministry of Higher Education, to advance precision measurement throughout industry. It might also be of interest to note in passing that the 1956 Director of what is apparently the most advanced research institution in machine building technology in the U. S. S. R., the Machine Practice Institute of the Academy of Sciences, appears in 1957 as the chief U. S. S. R. delegate to discuss the IGY Satellite Program at the U. S. National Academy of Sciences.

Conclusions

These are all matters of serious concern to this nation. Russian achievements in these areas must inevitably have a vital effect upon the American position within the community of nations. In the areas of measurement and standards, the National Bureau of Standards has a most critical national role. I believe that the Bureau's essential measurement research activities must be substantially strengthened. They must be reviewed in terms of both the ominous Soviet challenge and of effective domestic technological expansion. Quite apart from any direct comparison between Soviet competence and our own, we know of several areas where our inability to provide requested measurement standards services is impeding the work of scientists and engineers in other laboratories. Our research programs relevant to measurement and standards competence cannot be inferior to the central Russian effort if we wish to maintain our competitive position.

French Aircraft Invade US Civil Plane Market

Agreements have been concluded with three American firms to market French aircraft.

BEECH AIRCRAFT CORP. has announced a package price of $210,000 for the MS 760, high performance, four-place jet executive airplane made by Morane-Saulnier Co. of Paris. Parts will be shipped from France and assembled in New York.

Two Turbomeca Marbore IIC jet engines, rated at 883 lb static thrust, are the power units. Manufacturer claims the aircraft has a high speed of 403 mph, cruises at 350 mph, and has a range of approximately 1000 mi. Normal gross weight is 7725 lb.

REPUBLIC AVIATION CORP. is assembling and selling the Alouette II rotojet helicopter made by Sud Aviation. After a period of phasing-in of manufacturing components, the heli-

copter will be manufactured at Farmingdale.

The Civil Aeronautics Administration has certified the helicopter for commercial operation. This is the first French-built aircraft ever certified commercial, and the first gas turbine-powered (jet) helicopter of any make to be certified. (Sud Aviation expects to complete CAA certification test for the medium-range, twin-jet *Caravelle* commercial transport before the end of the year.)

The *Alouette II* is authorized to use the advanced Turbomeca Artouste IIB-1 turbine engine, rated at 400 hp.

TRIFRANCE, an American firm, is prospecting some 50 companies from Canada to Argentina to sell the Brequet *Deux Ponts* (double decked). This is a heavy cargo plane which the Brequet Co., in line with the French government's encouragement to export, believes has excellent commercial advantages.

This aircraft type has over 70,000 hr exploitation on the Mediterranean lines of Air France.

bearing lubrication and design problems

reviewed at SAE meeting in Detroit by aircraft and missile manufacturers

by John Kevern

Technical papers and discussions presented at the SAE Annual Meeting in Detroit made it obvious that aircraft and missile engineers feel more work is necessary by bearing manufacturers to reduce short run failures. At present a certain percentage of failures must be allowed for in planning and designing. To develop larger and more powerful engines, new bearing alloys and lubrication methods must replace the inadequate existing ones.

Bearing manufacturers, on the other hand, report they are doing as much development work as present material technology and analytical methods permit.

Two factors prevent more rapid progress: lack of data on mechanics of bearing failure, which in turn is hampered by lack of analytical techniques for non-destructive testing of steels. Such techniques as are available are not sensitive enough to discover and plot microscopic inclusions and other imperfections.

Mechanics of Failure

Tests on bearing geometry have not indicated any particular mechanical factor as a cause.

Misalignment is a major cause of failure. It is an inherent problem, since bearings must be fitted into seats and rabbets in the components.

Tight bearing fit, resulting from heat expansion, could cause early failure. The inner race runs hotter than the outer race; sometimes as much as 50°F.

Non-metallic inclusions of microscopic size can cause early failure, if present in the loaded portions of bearings. These inclusions become points of stress concentration. This results in crevice type failure, which starts below the surface.

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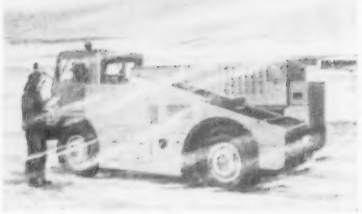
HUNTER ENGINE HEATERS



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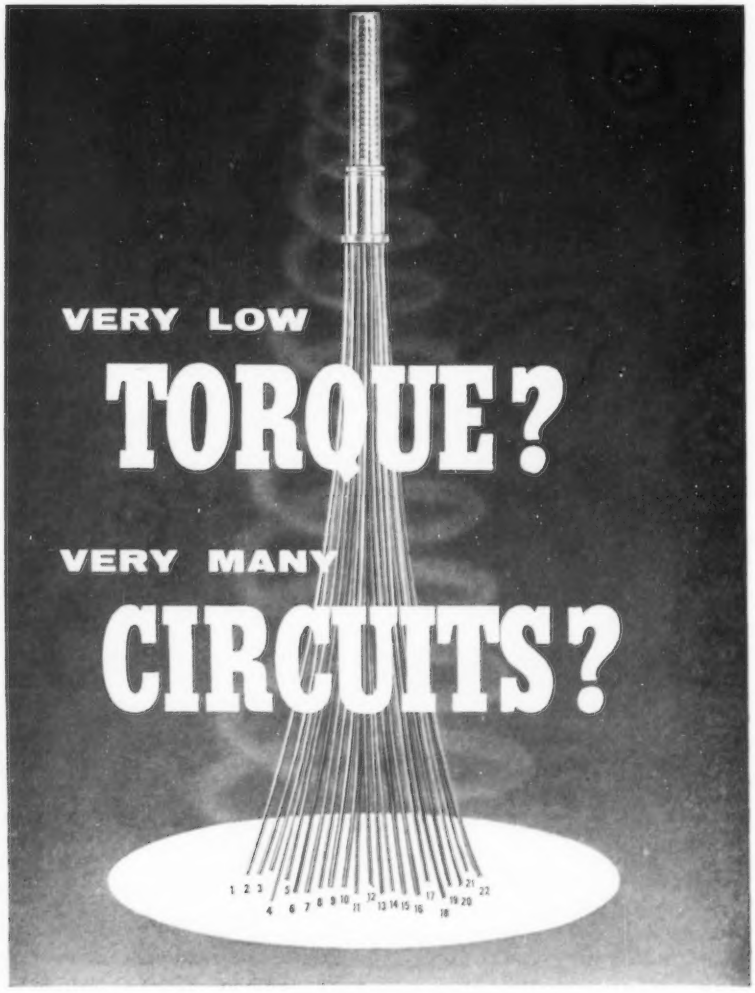
Circle 104 on Inquiry Card, page 65



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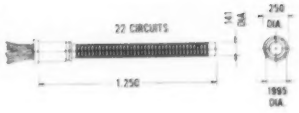

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industry notes

Continued from page 79

Material Considerations

Bearings usually start cold and work up to high operating temperatures. This eliminates use of materials which perform well at high temperatures, but inefficiently during the run-up from cold starts.

As temperatures increase, metal hardness decreases. Yet, in ball bearings, the proper degree of hardness must be maintained because of the high unit stress. This hot-hardness requirement causes problems with alloy content.

Techniques such as the use of vacuum melting are being developed to produce cleaner steel. But variations occur between heats.

Protective Atmosphere

For temperatures up to 1000° F an air-hydrocarbon mixture has been used to provide a reducing atmosphere and prevent oxidation. The hydrocarbon produces a secondary lubricating film on the bearing surfaces. The air-hydrocarbon vapor mixture appears practical for aircraft use, since jet engine fuel fulfills the hydrocarbon requirement very well. The lubricant is applied continuously at a slow rate. However, only bearings of all-ferrous construction can operate successfully in this protective atmosphere.

Environmental Factors

Military specs call for bearings to operate from —85 to 450°F for Category I, and from —100 to 600°F for Category II. As operating temperature goes up the loadcarrying ability of the bearing is reduced.

Continued on next page

Deep freeze treatment is used to insure heat stability.

Thermal decomposition places a maximum temperature limit on use of any grease. As the operating temperature increases, the lubricant breaks down and/or evaporates.

Other environmental conditions include humidity, sand and dust, salt spray, fungus exposure, and possible atomic radiation.

Mounting Factors

Reducing heat differential between ambient and bearing temperatures is accomplished by using hollow shafts, titanium sleeves inside the bearing, heat dissipation collars on the shaft between bearing and rotor, and increasing quantities of cooling air close to the bearing.

Large radial looseness is sometimes required because of large temperature differences between inner and outer races at the stabilized operating temperatures.

Double-sealed or shielded bearings must be checked for sufficient clearance to store unchurned grease. This usually requires 1/32 in. between cage and seals or shields.

Outer race creepage problems can be cured by using close fits between outer race and housing.

Misalignment

In a misaligned bearing, the balls are forced out of their normal track toward the shoulder of the groove. This causes strain and friction on the separator, and high loading and increased sliding of the balls. Usually, misalignment causes separator failure.

Bearings are mounted in a steel housing and pressed into aluminum end shields, which are rabbeted to the stator shell. Individual machining of these parts produces misalignment.

Research is being done to determine the amount of misalignment that can be tolerated, based on the statistical relationship between misalignment and bearing life.

Material Selection

Selection of high temperature materials has been handicapped by inadequate methods of screening. At present, materials are being tested for physical properties, including hardness and tensile, yield, and impact strength.

Bending fatigue work has been done at various hardnesses, with various cleanlinesses. Indications are that there is no correlation between bending fatigue and rolling fatigue.

In standard tests it is permissible to extrapolate bearing capacities at various speeds and bearing sizes, from results obtained with standard size bearings operating at nominal test speed. These tests are run at room temperature. When compared with high temperature data the results were confusing because of the variables involved.

The main problem in material selection is the lack of adequate inspection and testing. This is further complicated by variables such as material grain direction, corrosion, erratic thermal expansion, effect of finishes, geometry variables, and the inter-relation of bearing materials with lubricants.

Dry Lubricants

Few liquids or greases are useful at temperatures as high as 450°F. However, solid lubricants may be used at 600°F or higher. Best use of solids has been in resin-bonded films. There are other methods, but

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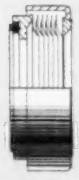
WHICH SEAL WILL SOLVE YOUR PROBLEM?

Seals drawn to same scale.				
Type of Seal	**Standard**	**Modified**	**Bellows**	**Shaft Surface**
Pressure (PSI)	1000	500	250	75
Speed (FPM)	15,000	15,000	15,000	15,000
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SEALOL

Continued from page 81

each has specific limitations. Some materials used for this purpose are: molybdenum disulfide, silver iodide, silver sulfate, sodium sulfate, boron nitride, graphite, and powdered Teflon.

Incorrect use of solid lubricants can accentuate operating problems, so each application must be considered carefully.

Silicone Lubricants

These materials are combinations of stable silicone fluids and suitable thickeners. They offer satisfactory lubrication over a wide temperature range, with low bleed and evaporation rates, high drop points, and good worked stability.

Factors important to proper use of these materials include speed, radial bearing load, bearing material, and clearances. In totally enclosed motors, the presence of silicone greases may increase brush wear slightly.

Mechanical Design Factors

High speed and high temperature, combined with requirements for minimum size, impose stringent limitations. The problem is to minimize wear without reducing capacity.

A close curvature raceway is desirable for optimum load distribution. Bearings in which lubrication is marginal or non-existent will wear, and curvature must be selected to minimize this.

The separator prevents contact and galling of adjacent balls. Choice of separator is partly limited by manufacturing considerations. Size of some miniature bearings excludes use of two-piece separator.

Provision must be made to exhaust the wear products and prevent locking the bearing. Generous clearances over the non-guiding surfaces have been found effective.

Sliding and spinning at the ball-to-race contact can be minimized by open curvatures and low contact angles.

Whether by Land or Sea Is Poser on Atom-Plane

The House Appropriations Committee marked "Off the Record" on hearing reports dealing with much of the information on the atomic plane. However, Air Force Secy. Douglas did tell the committee that there has been no approval given for accelerating the program.

Still alive, at this point, is the argument over constructing this plane as a land-based or seaplane type. The Navy hasn't given up its position that a seaplane should be the first one with an atomic power plant. Some fairly sturdy arguments

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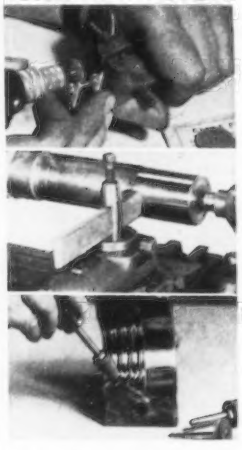

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Circle 107 on Inquiry Card, page 65

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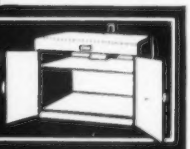

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are advanced in support of the premise that it would be based on and tested over water. This fact would reduce the danger of widespread radiation in case of a crash. Its ability to fly thousands of miles without refueling would make the plane highly useful for anti-submarine combat and patrol work.

Supporters of the land-based plane idea aren't convinced. The attitude of the Air Force, in particular, is that if the best interests of national defense are to be met the first operational atomic plane should be land-based.

On the question of using an existing airframe or one newly designed, there's also a difference of opinion. The Navy reportedly has suggested the reworking of one of a number of current large planes to house a nuclear engine. Air Force contracts already are underway with two firms, Convair and Lockheed, for the development of proposed designs for a special new airframe.

Rep. Price, D., Ill., says Congress wants assurance that funds granted in the future will be spent wisely. He fears interservice rivalry may further slow the atomic plane program.

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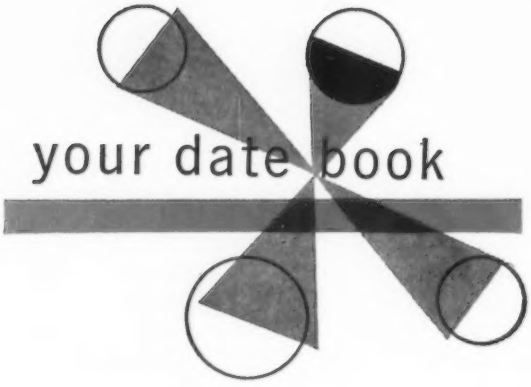

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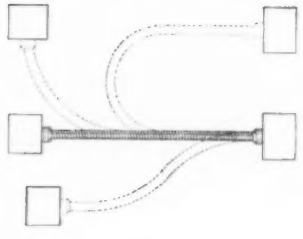

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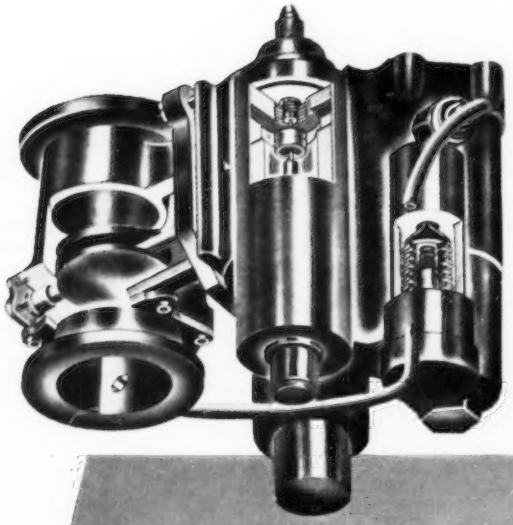

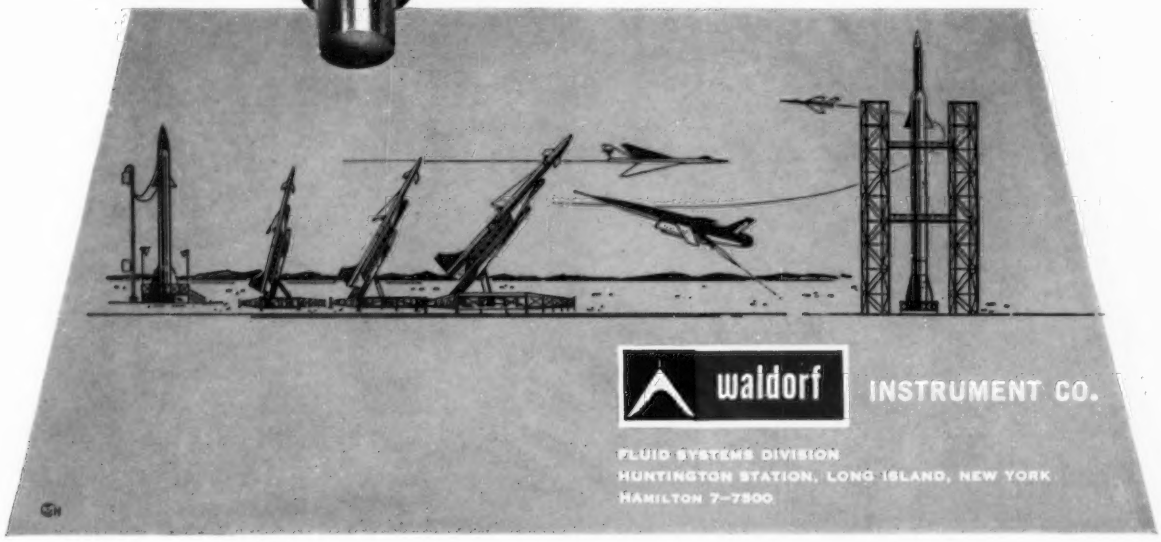

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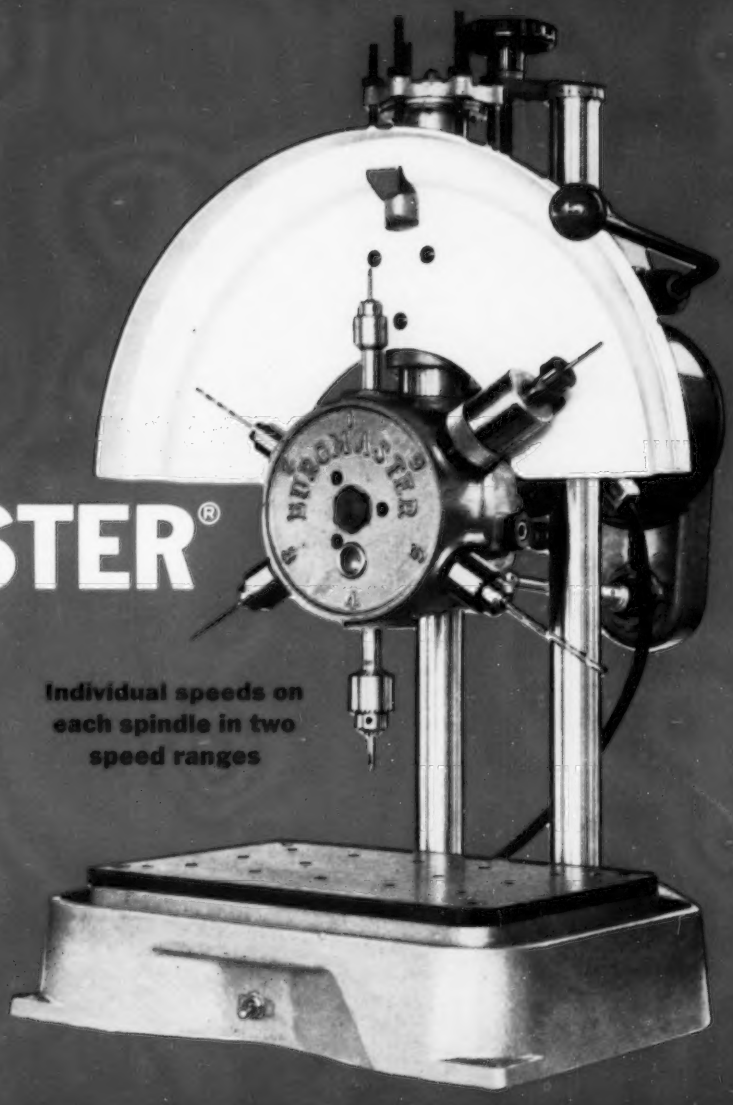

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